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THE DRAW CLOSED.



THE NEW TOWER BRIDGE OVER THE THAMES, LONDON.—THE DRAW OPEN.

THE NEW TOWER BRIDGE, LONDON.

THE long delayed and much discussed Tower Bridge has at length taken definite shape. The foundation stone of the structure was recently laid with elaborate ceremony by the Prince and Princess of Wales. The necessity for some additional accommodation, and for improving the connections between the north and the south sides of the river below London Bridge, has long been recognized.

On the north side of the river, east of this bridge, there is a population equal to that of Liverpool, Manchester, and Glasgow put together, while on the south side there is also a great and growing population which has suffered from the want of sufficient communication with the City side of London. By direction of the corporation, Mr. Horace Jones, the city architect, prepared, at various times since 1876, a number of schemes and reports on the subject. In October last the Court of Common Council selected Mr. Jones' design for a "bascule" bridge, which, whatever its merits from an engineering point of view, promises to be a handsome addition to the bridges of the metropolis. The excavations for the foundations were commenced last May, and lately the work has been carried on day and night. The bridge in its main features may be considered as a compromise between a high and a low level bridge. A high level bridge, it was considered, would have cost not only much more, but have involved steep gradients, long approaches, and a wholesale demolition of property on both sides of the river; while a low level structure would have prevented

portion of the towers in a hard red brick, with hard stone dressing. The foundation stone—weighing about five tons—was laid on the north side of the river. In the cavity underneath, the Prince laid the usual mementos of the period, and engraved upon it was the following inscription: "This memorial stone was laid by H. R. H. Albert Edward, Prince of Wales, K. G., on behalf of Her Majesty Queen Victoria, on Monday, 21st June, 1886, in the 50th year of Her Majesty's long, happy, and prosperous reign." Then follow the names of the Lord Mayor, the sheriffs, the chairman of the Bridge House Estates Committee, the city architect, the engineer, and the contractor. The bridge is expected to be finished in about 3½ years, and to cost altogether about £750,000.

The work is being carried on under the joint superintendence of Mr. Horace Jones, city architect, and Mr. John Wolfe Barry, engineer.

IMPROVED REGENERATIVE GAS FURNACE.

In September, 1885, a regenerative gas furnace was erected in the West Middlesex (Pa.) Rolling Mills, which has been in successful operation ever since. It is used for heating on the 10-inch mill, and has of late been connected by telegraph to the muck train, and is occasionally used for heating scrap fagots and reheating puddled steel blooms.

The following are statements of work done and fuel used at different periods, with costs, etc.:

May 14, 1886—Reheated 27,503 lb. puddled steel blooms with 28 bushels of coal, which, allowing 76 lb.

To prevent any misconception on the subject, it may be stated that the heaters' and helpers' wages are not included in the above costs, only such expenses as the use of natural gas would abolish. The above statements, or similar facts, we invite interested parties to verify by visiting West Middlesex Mills.

We have no extended record of the working of the furnace, for after first convincing ourselves of the great saving we were effecting both in fuel and iron, we felt easy and confident the furnace would always make a good record if it got half a fair show. The above examples were in no way special efforts to obtain extraordinary results, but turns taken at random, and unknown to any of the workmen except the gas man.

Taking natural gas at prices as published in Gas Supplement of *American Manufacturer*, we have for heating purposes in Pittsburgh 40c. to 60c. per gross ton, against 20c. to 27½c. with artificial or producer gas.

DESCRIPTION AND MODE OF WORKING FURNACE.

A, air valves; B, binder rods of furnace roof; C, coal hoppers on gas producers; D, air distributors; E, end plate of furnace; G, gas producers; H, hole for tapping out cinder; I, iron stack or chimney; J, gas chamber containing gas valves; K, ash pits of producers; L, floor level of mill; M, damper; N, front of furnace; O, gas passage into furnace; P, furnace plates at back; Q, cover plates for gas chambers; R, rail buckstaves; S, sight or stoke holes of producers.

The furnace is equally adapted for the use of natural



A, THAMES TUNNEL. B, TOWER SUBWAY. C, THE NEW TOWER BRIDGE, LONDON BRIDGE IN FRONT.

THE NEW TOWER BRIDGE, LONDON.

the passage of shipping, just as London Bridge does now. This consideration guided the Committee of the House of Commons in reporting strongly in favor of a bridge on the "bascule" principle. The new bridge will consist of three spans. The two shoreward spans will be on the suspension principle, somewhat like the ornamental Chelsea bridge. The chains will stretch from a tower on each shore to two "massive picturesque Gothic towers," to quote the official words, standing in the river at a distance of 200 ft. apart. The third section of the bridge, lying between these two towers, will have a double roadway, the lower at about the same level as London Bridge, viz., 29 ft., the upper at a height of 135 ft. above the high water mark. The lower or "bascule" portion of the roadway consists of two leaves which open upward by hydraulic power flush with the piers, thus leaving a clear opening of 200 ft., and sufficient head room for the largest vessel to pass under the upper roadway. Within the towers, right and left of this central span, there will be staircases and hydraulic lifts, by which foot-passengers may reach the upper roadway when the lower one is interrupted by the opening of the bascules. Foot passengers may thus always get across the river whether the lower bridge be open or not. Vehicular traffic will have to wait, but the official statement is that the "opening, passage of a vessel, and closing of the bridge could be accomplished in four or five minutes; but if even double that time once or twice in the course of a day is absorbed, it would be no material interference with the road traffic." The new bridge will be altogether about 500 ft. in length, the approach roads and land spans 60 ft. in width, and the center span 50 ft. wide. The lower portion of the piers up to the parapet will be built of gray granite, the upper

to the bushel, gives 2,138 lb. coal. This, divided by the iron made, makes the rate 173 lb. per gross ton of iron. On the same turn they heated scrap fagots which produced 3,660 lb. of scrap bars with a further consumption of 6 bushels or 456 lb. coal, being at the rate of 270 lb. coal to the ton of bars made.

Commenced charging the furnace about 5 A. M., and finished the turn at 3:40 P. M., making a turn of 10 h. 40 m., during which time 34 bushels or 2,584 lb. of coal were consumed, and 13-91 gross tons of bars made, which is at the rate of 186 lb. of coal to the ton, and the consumption of coal per hour 243-4 lb.

Allowing \$1.60 per ton for coal delivered in the bins of the gas producer, and \$1.75 per turn (which is the actual cost) for firing, removing ashes and cinder, would make the cost of the turn for coal and the necessary labor entailed by its use \$3.82, or at the rate of 27-5c. per ton of bars made. This is no exceptional case, but a fair average of working on this class of work.

For a couple of exceptionally low cases, we will take three turns of reheated blooms and two half turns of reheated 6-inch muck bar. The three turns of reheated blooms were worked in October, 1885. 46 35-2240 tons were heated with a consumption of 7,600 lb. nut coal, which is at the rate of 165-2 lb. coal per ton of iron, and the cost of fuel and labor on the above-mentioned basis would make it 24-6c. per ton.

The best record yet taken was in April, 1886, when two heats produced 22,400 lb. of reheated muck bar with 20 bushels of coal; this is at the rate of 152 lb. of coal per ton of muck bar, and at a cost of 21c. per ton. Next day two and a half heats made 28,000 lb. muck bar, with 26 bushels coal, or at a rate of 138 lb. per ton of iron, and at a cost of 20c. per ton.

as well as artificial gas, all the regenerative surface being devoted to heating the incoming air, the gas ports only receiving such heat as is conveyed through the bridge-walls. The change from the use of artificial to the use of natural gas may be made without loss of time on the furnace; and with three hours' notice of any stoppage in the natural gas supply, the change back to the use of producer gas may be made, also without loss of time, while the expense of the change is absolutely nil when once properly fitted up, all the trouble amounting to lighting the producer fires, and using the producer gas valves instead of the natural gas valves, and if there is any advantage in using a mixture of the two, there is no difficulty in doing so.

In using producer gas, no cooling tubes are required; the gas is produced in such close proximity to the furnace where it is used that it enters it with its initial heat, carrying with it in the gaseous state all the tar, soot, ammonia, etc., that would be deposited in cooling tubes and flues. We are aware that these condensable components of producer gas are held by some to be of very little importance, and we thought the same at one time, but think differently now; and unless it can be proved they are injurious to the heating properties of the gas, we think ourselves justified in discarding such cooling tubes and flues on the ground of unnecessary expense in construction.

The Heating Chamber.—This, of course, would vary in form and dimensions according to the purpose for which it was intended. At West Middlesex it is 15 ft. x 6 ft., with four small doors in front, and is operated in the following manner: At the commencement of the turn the furnace is charged from end to end, with the gas on at the end first charged, where it remains until the heat is ready; one end is then drawn; the gas and

air are then reversed, and the empty end charged again; then the other end is drawn, and the gas and air again reversed and the empty end charged up again, and so on, reversing at each drawing. With small piles and a double set of men at the furnace it is continuous.

The Gas Ports.—These were formerly narrow slits the whole width of the heating chamber, one at each end immediately behind the fire bridge, about 4 in. wide, delivering the gas into the furnace in one broad, thin sheet. This form of port was found objectionable on account of the distortion it suffered from the expansion and contraction of the furnace, the tendency being to bulge out the bridge in the center and close or partially close up that portion of the port. To remedy this, two or three $4\frac{1}{2}$ in. stays are built in, dividing the long narrow port into three or four, as the case may be, and this meets the case completely.

The Gas Producers.—These are rectangular chambers with arched roof, in which are the usual coal-hoppers, sight holes, etc. The grate is also of the ordinary kind, except we have no step grate in front. We abandon

from within a foot of the roof of furnace down to the floor of foundation. These chambers are divided up into narrow spaces separated by thin walls, and may be called vertical slits, and extend from top of chamber down to within 18 or 20 inches of the foundation, the clear space being left for cleaning out purposes. This arrangement affords no shelving for dust, etc., that may be carried over the bridge, and which in time chokes up regenerators of the ordinary checker-work type. The flame and hot gases enter the regenerative chamber immediately after having done duty in the heating chamber, and continue doing regenerative duty until they reach the bottom of the chimney, which they enter with only sufficient heat left to maintain a fair draught.

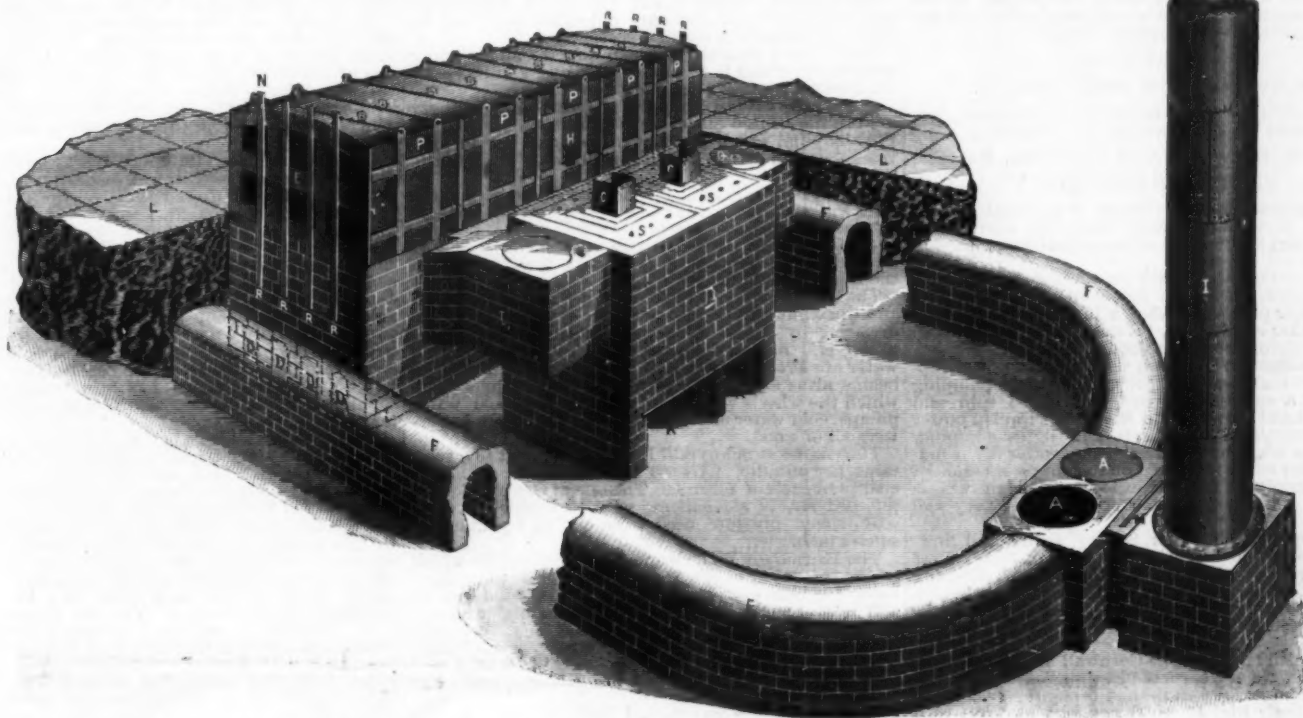
The Air Valves.—Neither of the valves nor the gearing are shown on the engraving, except that one valve appears open and the other closed, which is just as it should be. The valves are very simple and inexpensive, consisting of disks of cast iron suspended by a chain from the end of a beam similar to an old-fashioned weighing scale. There are two cast iron valve plates,

all the space necessary for opening and closing the gas valve. The valves, dampers, and regulators are all operated from the front of the furnace, so that the man in charge can immediately make any change in the flame he may wish.

The chimney is 50 ft. high and 42 in. in diameter (30 in. in diameter would be quite sufficient), made of 10 and 12 w. g. sheet iron, and is lined only about 5 ft. up, to give it more stability during wind storms.

The total cost of furnace and gas producers complete is put down at \$2,276.50. This includes all materials and labor, from the commencement of digging out the foundations to the time when the grate is ready for coaling to light up. Nothing, however, has been allowed for superintendence and drawings. All the furnace plates from the old draught furnace were used, except such as were broken; and the balance of the casting made up from old stock plates, doors, door-frames, cheeks, fore-plates, tie rods, bolts and nuts, etc., of the old furnace were all utilized, but charged up as new ones.

Cost of Repairs.—Some slight alterations in roof and



REGENERATIVE GAS FURNACE, WEST MIDDLESEX ROLLING MILLS.

done this for the convenience and comfort of the gas man, who can now clean his grate without being roasted to death. We give our grate eight or nine inches slope from front to back, and we think this answers quite as well as the flat grate bed and step grate front. We work our producers much hotter than the Siemens producers, and claim to be gainers by it.

For proportioning the producer to the furnace, we find that a grate space equal to half the area of the heating bed is quite ample, if the length of the bed does not come under $2\frac{1}{2}$ times the width. A square or circular furnace would probably require a rather higher proportion of grate area, while a long, narrow furnace might do with less.

Fuel.—We make no pretensions of burning dross or any other kind of rubbish. We have as yet discovered no device for burning and obtaining gaseous fuel from substances utterly destitute of it, our experience being that such substances absorb heat and choke up the fires, and are in every respect a nuisance. We find good clean nut coal to answer our purpose very well, in fact, better than anything else. We use no steam jet nor fan blast to force the producers, as they often produce faster than is needed.

The Regenerative Chambers.—These vary in form and extent with the convenience and space obtainable for the furnace site. If sufficient depth cannot be secured, the heating surface must be acquired horizontally by building spacious flues to the chimney, and, if necessary, dividing this space by thin walls. It will be observed that the air valves are as near the chimney as possible; this is to secure as much regenerative area as is required without building flues simply for the purpose of conveyance, or, in other words, to utilize all the flue space for regenerative purposes. The regenerative chambers proper are at each end of the furnace, and may be described as rectangular chambers running

one of which is seen in the engraving, containing the openings marked A. The plates are alike in every respect. The openings are somewhat less in diameter than the valves, the lower plate is set about 18 inches below the top plate, and covers a chamber connected with the chimney by the short flue containing the damper marked M. The top plate covers two chambers, each leading into its own air flue. The top chambers are separated by a wall under the center of the top plate and on the center of the bottom one. These plates are in line vertically, so that the valves (which are hung between the plates) cover the holes of each plate alternately when raised and lowered, and by this means the reversing of the air and spent gas currents is effected; thus, when one end of the beam is raised, the valve at that end closes the air passage to the furnace but opens the way from the furnace to the chimney, while at the other end of the beam the way to the chimney is closed and the air passage to the furnace is opened, so that it is only necessary to reverse the beam in order to reverse the air and spent gas currents. The quantity of air is regulated by hinged lids over each of the holes in the top plate, marked A.

Gas Valves and Chambers.—The valves are similar to those used for air valves, and are hung by a valve stem or rod. The gas chambers are at each end of the producer, and are marked J. They consist of two chambers, one within the other, with a space of 8 or 10 inches between them. The inner chamber is connected by a short flue with the gas producers, and closed on the top by a gas valve. The outer chamber is connected by a short flue with the furnace, and is built 12 to 14 inches higher than the inner chamber, and covered with a plate (marked Q) having a small hole in the center for valve rod to pass through. This 12 or 14 inches between top of inner and outer chamber gives

bridges were made in January last. Since that time no repairs have been required. This is the admission of our bricklayer, who finds all material and keeps the furnace in repairs by tonnage on the output. He says: "She has not cost me a dollar since January;" and this, observe, in the face of rough treatment by inexperienced hands.

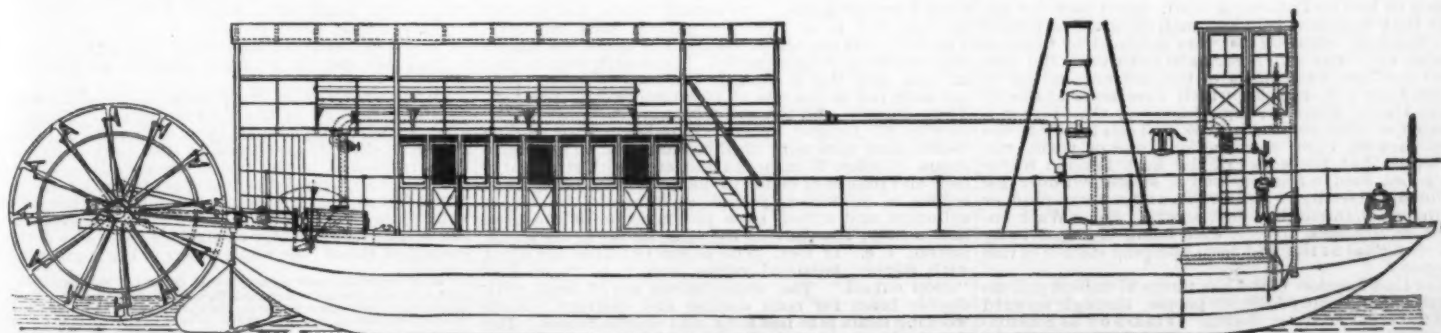
In the engraving, the foundation and flues are all laid bare, to show the construction as much as possible, while in practice all excavations are filled in again, except the cellar for the ash pits of producers. The flues gradually slope up from furnace until they reach the chimney. The air valve plate and top of chimney foundation are just on the floor level. The foundation of furnace and gas producers is about 8 ft. below the floor level. The flues are each about 50 ft. long, and a line of railway runs over both of them between the chimney and the gas producers. This is for the delivery of coal to the mill. The furnace and gas producers are under the mill roof, while the air valves and chimney are considerably outside.

One important point was almost overlooked, viz., the waste of iron. Our waste will compare favorably with the waste of any gas furnace using either natural or artificial gas.

W. A. WAPLINGTON.

STERN WHEEL STEAMER.

We illustrate a steel stern wheel steamer designed by Duncan Brothers, London, for navigation on South American rivers. The special feature of this boat is its great range of draught, enabling it, when half loaded, to cross the shallows in the higher reaches of the river, and as it nears the mouth and comes into deeper water, to carry the cargo collected on its way down stream. To obtain as large an efficiency as pos-



STEEL STERN WHEEL STEAMER.

sible under these varying circumstances, the paddle wheel is made with feathering floats. The dimensions of the boat are: Length of hull, 75 ft.; a beam of 15 ft.; and 6 ft. depth of hold. She can carry when laden 75 tons dead weight of cargo, besides fuel and water, and has sleeping accommodation for a number of passengers.

The promenade deck over the cabin is 34 ft. long, and is protected from the sun's rays by an awning. The hull is made entirely of steel, and divided into compartments by watertight bulkheads, arranged in such a manner that in the event of any compartment being stove in by collision with a rock or other obstacle, the vessel would not be in danger of sinking. She is fitted with a pair of powerful high pressure horizontal engines, provided with link reversing gear. Steam is supplied from a steel boiler of the torpedo boat type, placed in the fore part of the boat, having an extra large firebox suitable for burning wood. A fan on the centrifugal principle, fitted to the front of the ash box, drives air into the furnace from under the grate bars. When light, this vessel will steam at a speed of ten knots per hour, and being fitted with two rudders, is completely under the control of the helmsman stationed in the wheelhouse above and forward of the boiler.—*Mechanical World.*

SIBLEY COLLEGE LECTURES.—X.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

By E. D. LEAVITT, Jr., of Cambridge, Mass.

PUMPING MACHINERY.

OF the almost endless variety of mechanical constructions, none have more efficiently contributed to the comfort and welfare of mankind than pumping machinery.

Devices for elevating water are among the most ancient on record. It is both interesting and profitable to study their progress as shown in the works of Agricola and other old writers. Ewbank's Hydraulics also covers the history of the subject quite fully.

The introduction of steam as a motive power supplied that which was indispensable to make pumping machinery a success. It was possible to spin and weave by hand power, and the wind supplied power for the propulsion of vessels and light pumping. Deep mines could not be freed from water by windmills, neither could modern London obtain a sufficient domestic supply by Peter Maurice's undershot wheels and 7 inch plunger pumps, which answered very well in 1782.

The Marquis of Worcester, Savery, Papin, and Newcomen accomplished considerable, but to James Watt must be credited the great development in pumping machinery, which has been made possible by his improvements in the steam engine, and this development has accordingly taken place within the last hundred years.

The Cornish mines in the Cornwall mining district of England were the earliest beneficiaries as the result of Watt's genius. Smeaton had brought Newcomen's engines to their highest efficiency, but at their best they were most extravagant steam users. Compare Plates V. and X. in Farey on the Steam Engine, and you will see at a glance the grand advance made by Watt in economizing heat.

All that Watt needed to accomplish the best that has been reached by the engineers of the present day, was the means of obtaining first class materials and workmanship. I have before me a copy of one of his patents, dated July 3, 1783, which clearly demonstrates that he fully comprehended the value of using steam expansively, while, curiously enough, he mentions devices for accommodating a varying effort to uniform work.

The Cornish engine, as you are aware, consisted of a single acting steam cylinder which operated a series of plunger pumps attached to a long wooden rod reaching to the bottom of a mine. Steam was admitted to the upper side of the piston, and by its descent raised the opposite end of the beam, to which the rod and its plungers were connected. The water by the descent of the plunger rod and plungers was forced upward. The great weight of the mass moved enabled the use of expansion to be carried to any desirable extent. Hence we find that as far back as 1843, a duty of 100 millions was reported with a consumption of 94 lb. of coal. Later on, the duty of Cornish and other engines will be more fully considered.

The pumps used in Cornwall were single acting plungers with clack valves; later, double, treble, and four beat valves were substituted, with excellent results.

The usual lift, as it was termed, for each plunger was forty fathoms; that is, each plunger forced water 240 feet high, into a cistern from which it was taken by another plunger.

In the Cornish Bull Engine, the beam is omitted, the piston rod being coupled directly to the plunger rod, which is placed beneath the steam cylinder. Steam being admitted below the piston, raises the rod and plungers, which descend by their own gravity, as in the case of beam engines.

The remarkable economy of the Cornish engine in mine pumping led to its introduction for public water supply in 1803 by Boulton & Watt, but it does not appear that this firm achieved such remarkable results in respect to economy as were obtained by builders located in Cornwall. It seems to have been the custom for different engineers of the different mines to design their own engines, which were built at the famous Hagle Foundry, by Harvey & Co. I saw a number of these engines in 1885, and can testify to the excellence of their construction; one of them, the "Victoria," at the works of the East London Water Co.'s Lea Bridge Station, had a steam cylinder 100 inches diameter by 11 feet stroke, and a pump plunger 60 inches diameter by 9 feet stroke. Some Watt engines, dating back to 1809, were being changed to fly wheel engines at the Old Ford pumping station of this company.

The East London Water Co. pump 66 million gallons per day, and supply 1,300,000 people, through upward of 1,000 miles of street mains. It takes on as consumers 60,000 people per annum, and is the largest of the London water companies.

The Cornish engine, for city water supply, was found to be very costly, as a large machine would pump but a moderate quantity of water; because the speed was limited and the steam and pump ends were both single acting. Accordingly, fly wheel engines were resorted to, and have generally superseded the Cornish type.

The most economical and efficient pumping engine in use in Europe is that known as the Simpson engine, from the name of the original builders, Simpson & Co., of London. These engines are compounds, with beam and fly wheel and cylinders of the Woolf type, placed at one end of the beam, and the pump and fly wheel at the other. The pump is of the bucket and plunger construction, as exhibited on the drawing of the Lawrence Water Works pump; but the supplementary discharge valves have but recently been adopted in the English practice, having been originally used in this country. As will readily be understood, the bucket and plunger pump is double acting, having, however, but one suction on the up stroke and discharging one-half the capacity on each stroke.

The Simpson engine works with great smoothness and economy; and the only objection that can be brought against it is the first cost.

We will now turn to American practice in pumping machinery, which is the most extensive, and possesses the greatest variety of any in the world.

Among the earliest examples of pumping machinery used in the United States were water works engines at Philadelphia, which were put in operation between the years 1801 and 1803, of which the following is a description.

The engines were built by Nicholas Roosevelt, on the river Passaic. The one at Central Square had a steam cylinder 33 inches diameter by 6 feet stroke, working a double acting pump, 18 inches diameter by 6 feet stroke, and raised water 51 feet into a tank placed on the top of a building.

The other engine, at the corner of Schuylkill, Front, and Chestnut streets, had a steam cylinder 40 inches diameter by 6 feet stroke, working a double acting pump 17½ inches diameter by 6 feet stroke, raising water about 55 feet. In both these engines, the lever beams, arms and shafts of fly-wheels, bearings upon which the wheels were supported, hot and cold water pumps, cold water cisterns, and even the steam boilers were all of wood.

The engine at Schuylkill Front pumped, at 16 revolutions per minute, 1,474,560 ale gallons per 24 hours, coal 70 bushels of Virginia. The one at Central Square pumped 962,520 ale gallons, with 55 bushels of same coal; steam pressure used, from 2½ to 4 pounds per square inch.

The Fairmount Waterworks at Philadelphia, which utilize the power of the Schuylkill River at that point, have long been celebrated. They were started Oct. 23, 1823, with breast wheels of the following dimensions:

No. 1 wheel, 15 feet diameter, 15 feet long, drove one pump 16 inches diameter, 4½ feet stroke. Wheels Nos. 3 and 3 were 16 feet diameter, by 15 feet long, and each drove one pump 16 inches diameter and 5 feet stroke.

The first turbine was started Dec. 16, 1851. It was 7 feet diameter, and drove one pump 16 inches diameter by 6 feet stroke. At present, there are 13 pumps driven by 7 turbines at Fairmount, viz., No. 1, described above, capacity 2,000,000 gallons per day; Nos. 3, 4, and 5 are 10 feet 3 inches diameter, each driving two pumps 22 inches diameter by 6 feet stroke, capacity of each wheel 6,000,000 gallons per day; Nos. 7, 8, and 9 are 9 feet in diameter, each driving two pumps of 18 inches diameter and 6 feet stroke, capacity of each wheel 4,500,000 gallons per day. Aggregate capacity of water power pumps, 33,500,000 gallons per day.

Progress in water works pumping machinery since the Fairmount works were commenced has been rapid; and there are at present in the United States and Canada no less than 511 pumping works, containing machinery of an aggregate capacity which probably exceeds 2,350,000,000 gallons per diem.

Among the cities whose pumping machinery is worthy of mention, either from peculiarities of construction or its great capacity, may be mentioned: Montreal, Ottawa, Hamilton, and Toronto, Can.; Boston, Lowell, Lynn, and Lawrence, in Massachusetts; Providence and Pawtucket, in Rhode Island; Brooklyn, Buffalo, and Saratoga, N. Y.; Jersey City, N. J.; Philadelphia and Pittsburg, Pa.; Cincinnati and Cleveland, O.; Louisville, Ky.; St. Louis, Mo.; Chicago, Ill.; and Detroit, Mich.

In the cities above named, there will probably be found as great a variety of good, bad, and indifferent pumping machinery as has ever been collected in an equal number of places anywhere in the world. A brief description of the most prominent types and their peculiarities will now be given.

The most extensive steam pumping works in America are those located at Chicago, Ill., which have an aggregate daily capacity of 134,500,000 United States gallons. They are all beam and fly wheel engines. Those on the North Side Works are single cylinder, while those at the West Side Works are compound. The first engine was erected in 1853, and has a capacity of 7,500,000 gallons per 24 hours. It has a steam cylinder 44 inches in diameter, with a stroke of 9 feet, and operates two bucket pumps 34 inches in diameter by 5 feet 6 inches stroke. The second engine was erected in 1857, and is of 13,000,000 gallons daily capacity. The third was erected in 1867, and is a double engine of 18,000,000 gallons capacity. The fourth was erected in 1873, and has a capacity of 36,000,000 gallons, but has been run at the rate of 43,000,000 gallons per day. These engines, and those of 1867, were designed by Mr. Dewitt C. Cregier, lately Commissioner of Public Works, and were built at Pittsburg, Pa. They have steam cylinders 70 inches in diameter, with stroke of 10 feet, and pumps 37 inches in diameter, with plungers 40 inches in diameter, placed underneath the steam cylinders, and driven by a prolongation of the main piston rods; thus having the same stroke as the steam piston rods, i. e., 10 feet. The steam cylinders are fitted with double balanced valves, and have the Sickles "drop out-off." The water valves are of brass, with double beats for both suction and delivery. Each working beam is 28 feet long, and weighs 20 tons. The fly wheel, common to both engines, is 26 feet in diameter, and weighs 40 tons. The cost of these engines, includ-

ing 3 boilers 11 feet in diameter and 28 feet long, was \$188,400.

At the West Side Water Works, there are four compound beam engines of the Simpson type, having high pressure cylinders 48 inches in diameter by 6 feet stroke, and low pressure cylinders 76 inches in diameter by 10 feet stroke, both fitted with Corliss valves and valve gear. They were designed by Mr. A. A. Wilson, and built by the Quintard Works, of New York. The pumps are of the bucket-and-plunger type, with 51 inch buckets and 36 inch plungers, with stroke of 10 feet. There is one pump to each engine, located directly underneath the low pressure steam cylinder, and worked by a prolongation of its piston rod. The engines are so arranged as to be worked singly or in pairs, by coupling on the outboard ends of the fly wheel shafts. The beams are each composed of two wrought iron plates, 36 feet long, 7 feet deep at center, and 2½ inches thick, spaced 15 inches apart. Weight of each beam, 30 tons. Each fly wheel is 32 feet in diameter, and weighs 60 tons. The first pair of engines were erected in 1876, and are fully described in the first annual report of the Department of Public Works of Chicago. Their cost, including six boilers, was \$243,500.

The second pair were completed in 1884, at a cost of \$257,500, which also covers boilers. The only difference in the engines is in the water valves of the main pump, two of which are fitted with the Morris rubber band valves, similar to those used at the Kent Water Works in England, and the last two are double beat valves. The performance of all these engines is highly satisfactory.

The St. Louis (Mo.) Pumping Works probably rank next to Chicago in point of capacity, and in work actually performed exceed them, as the average head against the pumps at St. Louis is very nearly double that at Chicago. For the St. Louis high service, there are three simple beam and fly wheel engines having a capacity of 24,000,000 gallons per diem. There is also a low service, having two Cornish Bull engines, and two beam and fly wheel engines of very peculiar construction, designed by Mr. Worthen, of New York. It is very difficult to get at the performance of the St. Louis machinery, which has been singularly unfortunate in break downs, requiring great expenditure for repairs.*

At Milwaukee, Wis., a fine pair of Simpson compound engines, working bucket-and-plunger pumps, were erected in 1874. They have a capacity of 16,000,000 gallons per twenty-four hours. A second engine, having a capacity of 12,000,000 gallons per twenty-four hours, was erected in 1881, and has a good record for economy. In this engine, the steam cylinders and pumps are in the same vertical line, the connection to the beam being made between the two steam cylinders; the beam center being carried, as it were, on a hip in the low pressure cylinder framing. The low pressure cylinder is 66 inches in diameter by 5 feet stroke, and the high pressure 24 inches in diameter by 5 feet stroke. They are fitted with Corliss valves and valve gear. The pump is of the bucket-and-plunger type, having a plunger 30 inches in diameter, and bucket 41-78 inches diameter, with stroke of 5 feet. This engine was designed by Mr. Edwin Reynolds, and built by E. P. Allis & Co., of Milwaukee.

At Detroit, Mich., new works have been recently constructed, which contain two compound beam and fly wheel engines, designed by Mr. John E. Edwards, the engineer of the board. These engines have high pressure cylinders 42 inches in diameter, placed under one end of the beam; and low pressure cylinders 84 inches in diameter, located at the opposite end of the same. The piston rods of both cylinders pass through the bottom, and operate piston pumps 40½ inches in diameter, each being double acting. The stroke of both steam and pump pistons is 6 feet. At the high pressure end of the beam the same is prolonged sufficiently to obtain a suitable connection to the crank, which thus has a throw exceeding the stroke of steam pistons. The steam distribution valves are of the balanced, double beat variety. Each pump has 48 brass backed, leather flap valves for suction, and 116 rubber disks, 9 inches in diameter, for delivery valves. The Detroit engines work with remarkable smoothness and economy.

The Toronto and Montreal works, as well as those at Buffalo, N. Y., are supplied, among others, with Worthington duplex engines, which will be described later.

The cities of Cleveland, O., and Louisville, Ky., have each fine examples of the Cornish engine. The former city has in recent years erected engines of the Worthington duplex type, having an aggregate capacity of 28,000,000 gallons per diem; while the latter has had plans prepared for a compound beam and fly wheel engine, of 16,000,000 gallons per diem, to be raised against 200 feet head, to be constructed in the near future.

Cincinnati, O., possesses a great mechanical curiosity shop, where may be found engines the like of which have never been erected at any other works, nor are ever likely to be. The great Shields engine, which has a steam cylinder 100 inches in diameter, and a stroke of piston of 13 feet, was, some years since, illustrated in *Engineering*.

Most of the Cincinnati engines have only one merit, viz., that of being odd. Messrs. Robert Wetherell, of Chester, Penn., have, however, recently erected some vertical compound engines, which are expected to be a great advance on previous practice in the Queen City.

Pittsburg can most justly claim the most ponderous pumping engines in the United States. These engines are of the horizontal type, with vertical plunger pumps worked from bell cranks, which are operated by links connected to the piston crossheads. The bell cranks are so arranged as to impart to the pump plungers a fast and slow movement, similar to that of the wrist plate used in Corliss valve gear. The plungers are weighted sufficiently to displace the water without the aid of steam; the whole power of the engines being

* It is stated on good authority that, of all the St. Louis pumping engines, the performance of the Bull Cornish machines has been the most satisfactory, their low cost for repairs having made them practically the cheapest engines to operate. When it is remembered that the ablest American talent was employed in the design and construction of the St. Louis works, the fact that the most antiquated type of engine has proved the most efficient becomes highly suggestive.

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exerted in raising the weighted plungers, which are connected on opposite sides of the bell crank main centers. There are two simple engines, with cylinders 62 inches in diameter, and 14 feet stroke of pistons; and two tandem compound engines, with high pressure cylinders 62 inches in diameter, and low pressure cylinders 106 inches in diameter, with 14 feet stroke of pistons.

Each engine operates two plungers, 40 inches in diameter, by 11 feet 3 inches stroke, and the head against the pumps varies from 340 to 360 feet. The pressure of steam used is 120 pounds per square inch, and the steam valves are of the single beat type in ordinary use on Western river steamboats. Each pair of engines has one fly-wheel in common, 33 feet in diameter, and weighing 100 tons.

The cranks of the engines were at first set at right angles with each other, but were afterward changed so as to be opposite, in order to secure smoother action in the pumps. The pump valves are single beats, of brass, and their action for a long time was simply terrific; ocular proof of which may be obtained by inspecting the scrap heap in front of the pumping station at Negley's Run. The compound engines have been discontinued, as far as the low pressure cylinders are concerned, and are now run as simple engines. The changing of the cranks from right angles to opposite, and placing a relief water escape on the delivery side of the pumps, has effected a wonderful change in the action of the Pittsburg engines, which worked during a late visit of the American Society of Mechanical Engineers with a fair degree of smoothness. The cost of the two pairs of engines was very nearly \$1,250,000, exclusive of foundations; and it is probably the most expensive plant, for its value and capacity, that was ever erected in any country.

The city of Philadelphia has, in addition to its water power pumping machinery, steam power of an aggregate capacity of approximately 125,000,000 gallons per day, distributed at five different stations. There are nine Worthington duplex engines, having an aggregate capacity of 78,000,000 gallons; one Simpson compound engine; two inverted compounds of the marine type; and one double horizontal engine, recently erected.

Jersey City, N. J., has three Cornish beam engines, and four Worthington duplex engines.

Brooklyn, N. Y., has three beam and fly-wheel engines, having steam cylinders 85 inches in diameter, with 10 feet stroke of pistons, and rated at 15,000,000 gallons each per day. This city has recently erected some direct acting steam pumps of the Davidson type.*

One of the best pumping engines in the United States is the Morris engine, so called, at Lowell, Mass., which was started in 1873. This engine is of the Simpson type, having a beam and fly-wheel; the former being supported upon the air vessel, which is made very massive for the purpose. The high pressure cylinder of this engine is 36 inches in diameter, and has a stroke of 5 feet 1½ inches. The low pressure cylinder is 57 inches in diameter, and has a stroke of 8 feet. The main pump, which is on the crank end of the beam, is of the Thames-Ditton bucket and plunger construction, 36 inches diameter of bucket, 25 ½ inches diameter of plunger, with stroke of 6 feet. The rated capacity is 5,000,000 United States gallons in 24 hours. The pump valves are double beats, 17 inches in diameter. There are 7 suction valves and 3 delivery valves in addition to the bucket valve. After running this engine a while, the delivery valves were taken out, the bucket valve alone being used for delivery.

The steam distribution valves for the cylinders are of the double balanced variety, and are operated by cams on a revolving shaft. The high pressure inlet valves are provided with an automatic cut off, which is controlled by a governor. The duty of the engine, for the year 1883, was 89,739,000 foot pounds per 100 pounds of coal consumed for pumping, and 75,709,950 foot pounds per 100 pounds of coal used for all purposes at the engine house. The average annual duty of the engine for 10 years, on coal used for pumping only, is 99,307,055 foot pounds per 100 pounds of coal.

The cities of Lynn and Lawrence, Mass., have compound beam and fly-wheel engines of a novel type.† In these engines the steam cylinders are placed very nearly under the main center of the beam, and are inclined outwardly, at the proper angle to connect with dependent projections, cast on the beam; the low pressure cylinder being connected in the pump end of the beam, and the high pressure to the opposite or crank end. The pistons thus have opposite movements; and the connections between the cylinders, for carrying the steam from the high pressure to the low, are very short and direct. The strain on the beam is, by this construction, reduced to a minimum. The Lawrence engines, which are coupled to one fly-wheel shaft, have high pressure cylinders 18 inches in diameter, and low pressure cylinders 38 inches diameter, both having a stroke of 8 feet. Each engine works a single Thames-Ditton pump, having a 26 1-8 inch bucket and 18½ inch plunger, with stroke of 8 feet. The rated capacity is 2,000,000 gallons in 10 hours for each pump, to get which a speed of 16 revolutions per minute is maintained. The steam distribution valves are gridiron slides, which are operated by cams, and have a very short horizontal movement. The high pressure inlet valves have an automatic cut-off controlled by a governor. Originally, the pumps of the Lawrence engines were fitted with brass double beat valves, 16 inches in diameter; there being 7 suction valves and 4 auxiliary discharge valves in addition to the bucket, for each pump. The percentage of useful effect obtained with the double beat valves was 81 per cent. of the indicated power in the steam cylinders. After running about a year, the double beat valves were replaced by annular, cast iron valves, faced with rubber, when the percentage of useful effect rose from 81 to 91, and probably averaged 90 per cent.

The duty of the Lawrence engines for the year 1883 was 99,537,317 foot pounds per 100 pounds of coal consumed for pumping, and 97,471,681 foot pounds per 100 pounds of coal consumed for all purposes at the pump-

ing station. The cost of raising 1,000,000 gallons one foot high, all expenses included, averaged \$0.0461.*

We find at Providence and Pawtucket, R. I., two very remarkable engines, designed and built by Mr. George H. Corliss of Providence. These engines display in general, and in detail, the great ingenuity for which their designer is so celebrated; and their performance has been wonderful as well. The Pawtucket engine was first started Jan. 30, 1878, and has been daily used since that date. In this engine there is a high pressure cylinder 15 inches in diameter, and a low pressure cylinder 30 inches in diameter, both with stroke of 30 inches. These cylinders are placed side by side, horizontally, with piston rods connected directly to double acting water plungers, which are 10-52 inches in diameter. The plunger rods are keyed to cross heads, from which links run to vertical beams; the link connection being made in the center of the beam, and the fulcrum at the lower end. From the upper end, connecting rods are coupled to cranks, which are placed at right angles, and have a throw equal to twice the stroke of the steam piston and plungers. The bearings for the crank shaft are carried on top of the pump air chambers, and A braces run from the same to the main center pedestals of the beams. The cylinders are steam jacketed, and fitted with Mr. Corliss' latest improved valve gear. The pump valves, for both suction and delivery, are simple annuli of phosphor bronze, about 1-23 inch thick, and 3¼ inches outside diameter. Each valve is seated by a volute spring of thin flat section, also of phosphor bronze. The lift of the valve does not exceed ¼ inch, and there are a sufficient number of them to give a water way equal to the cross section of the plunger. There is a very large receiver between the cylinders, into which the condensed water from the steam jacket, pipes, and receiver itself, after being re-evaporated into superheated steam, is discharged, with the effect, not infrequently, that more steam can be accounted for on the low pressure indicator card than came out of the high. The re-evaporation of the condensed water before referred to is performed in a coil, placed in the boiler flue. The Pawtucket engine, as a piece of mechanical construction, is exceedingly graceful; and the workmanship is unexcelled by that of any other pumping engine that has come under the writer's notice. During the four years ending Jan. 31, 1884, the total number of gallons raised by the Pawtucket engine was 1,709,094,370 against 262-75 feet average head. This work was done with total consumption of coal at the engine house amounting to 3,629,296 pounds, which gives the average duty for the four years of 164,904,548 foot pounds per 100 pounds coal consumed. Deducting 80,395 lb. of coal used for heating the engine house, the duty becomes 108,750,722 foot pounds per 100 pounds of coal. The highest monthly duty for the year was in November, 1882, when it reached 121,332,036 ft. lb. per 100 pounds of coal, after deducting 800 pounds used for heating. The average revolutions made by the engine were 45-36 per minute. The cost of raising 1,000,000 gallons one foot high was \$0.0486. It is hardly necessary to say that this performance has been rarely, if ever, equaled.

Mr. Corliss erected, in 1881, at the Pettaconset pumping station in Providence, a pair of compound beam and fly-wheel engines, of 9,000,000 gallons daily capacity, under a guarantee that they should develop a continuous duty of 100,000,000 foot pounds per 100 pounds of coal in regular work. These engines have one high pressure cylinder connected to one beam 18 inches in diameter and 6 feet stroke, and one low pressure cylinder connected to the other beam, 30 inches in diameter and 6 feet stroke; each engine working two single acting plunger pumps, 19 inches diameter by 36 inches stroke. There are 96 suction and 96 delivery valves for each pump, of the construction previously described for the Pawtucket engine. The fly-wheel is 25 feet in diameter, and weighs 31 tons. For the year 1883 the Pettaconset engines ran, on 290 different days, 3,952-09 hours, and pumped 1,489,735,981 gallons of water, against an average head of 177-45 feet. The total coal consumed was 2,077,135 pounds, including wood used for starting fires; charged 3 pounds of wood equal 1 pound of coal. The average duty for the year was 106,048,000 foot pounds per 100 pounds of coal.

It should be remarked that the splendid results obtained at Pawtucket and Providence are due to: first, the fact that Mr. Corliss was untrammelled in arranging his designs to suit the work to be done, and was very successful in his adaptations; secondly, that the head against the pumps, particularly at Pawtucket, is very heavy, so that the percentage of power lost in putting the water through the pumps is very small; thirdly, to high pressure steam and high expansion; fourthly, to most admirable handling of the machinery by the engineers in charge.

MINE PUMPING MACHINERY.

One of the earliest steam engines, of any size, introduced into America, was erected about the year 1763, at the Schuylkill copper mine, situated on the Passaic River, in New Jersey. All its principal parts were imported from England; and Mr. Hornblower (the son, it is believed, of the well-known engineer of that name) came to this country for the purpose of putting up and running this engine.

At the time when the manufacture of the engines for the Philadelphia Water Works was commenced, and as late as the year 1808, we find five engines, in addition to the one above mentioned, noticed as being used in this country; two at Philadelphia Water Works; one just about being started at the Manhattan Water Works, New York; one in Boston; and one in Roosevelt's Saw Mill, New York; also a small one, used by Oliver Evans to grind plaster of Paris, in Philadelphia. Thus at the period spoken of, out of 7 steam engines known to be in America, 4 were pumping engines.

In the coal regions of Pennsylvania a simple, high pressure, single acting Bull engine has been extensively adopted; the dimensions usually run from 30 inches to 80 inches diameter, and a very common stroke is 10 feet. At the Empire shaft in the Schuylkill coal region, there is a very fine pair of these engines, with 80 inch cylinders, working 24 inch pumps. The stroke of both steam pistons and pumps is 10 feet. These Bull

engines are placed either vertically or on an incline, as is most convenient for the workings. The water valves are made either double, triple, or four beat, according as the pumps are large or small; and the beats are usually flat and faced with leather.

Many flap-valves are also in use. These are frequently arranged on conical seats, and work very well. The Bull engines, from their strength and simplicity, give very little trouble, working year after year with astonishing freedom from accidents and slight cost of repair. No attempt is made to economize fuel, which consists mainly of culm, which would otherwise be wasted. Of late, direct acting steam pumps placed under ground have found much favor with mine operators on account of their portability and small first cost. They usually range in size from 8 inch steam and 5 inch water cylinders by 12 inch stroke to 80 inch steam and 14 inch water cylinders by 36 inch stroke. Great numbers of these pumps are in use all over the United States.

A pumping engine which is remarkable for its size and peculiarities of construction is located at the Lehigh zinc mine, at Friedensburg, Pa. It was designed by Mr. John West, the company's engineer, and built by Merriek & Sons, of the Southwick Foundry, Philadelphia. It is a beam and fly wheel engine, the steam cylinder being 110 inches in diameter, with a stroke of 10 feet. There are two beams on the same main center, from the outer end of which a double line of bucket and plunger pumps is operated. The crank shaft is underneath the steam cylinder; and there are two fly wheels, one on each end of the shaft, the crank pins being fast in the hubs. There are two connecting rods, which are attached one to each end of an end beam pin 28 inches in diameter. The main center and crank shafts are also 28 inches in diameter; each of the two plunger-poles is 24 inches by 30 inches in section; and all the working parts are in proportion to those heretofore mentioned.

Perhaps no mining district has ever had to contend against greater difficulties in pumping than have faced the engineers at the celebrated Comstock lode, Virginia City, Nev. The mines are of great depth, in some instances 3,300 feet, and the water is hot, rising to 100° Fahr. The machinery collected at this location is of great variety and magnitude. There are many Davey engines, both horizontal and vertical. The Union and Yellow Jacket shafts have compound fly wheel engines of very great power; the former having a beam, and the latter being horizontal, with cylinders placed side by side and pistons connected to a massive cross-head, from the ends of which connecting rods lead to crank pins located in the hubs of the fly wheels, which are overhung upon the ends of the main shaft. From the center of the cross-head, a link runs to the main pump bob, which operates a double line of 16 inch pumps, 10 feet stroke. The steam stroke is 12 feet. Depth of shaft, 3,300 feet.

The pumping machinery used in the iron and copper districts of Michigan usually consists of Cornish plunger pumps, which are operated by geared engines; the latter making from 8 to 16 strokes to one of the pumps.

The largest plant of this type yet erected is that of the Calumet and Hecla copper mine, at Calumet, Mich.* There are two lines of pumps, varying in diameter from 7 inches to 14 inches, and with an adjustable stroke varying from 3 feet to 9 feet. The object of the adjustable stroke is to diminish the capacity of the pumps in the dry season. Each line of pumps is driven from a crank placed on a steel spur wheel shaft 15 inches in diameter, making 10 revolutions per minute. The mortise spur wheels have a diameter of 22½ feet at the pitch line, with two rows of teeth, each 15 inches face. The pitch is 4-72 inches. Engaging with the mortise wheels are pinions of gun iron 4 feet 6 inches in diameter, placed on steel shafts 12 inches in diameter, and making 50 revolutions per minute. The 12 inch pinion shafts are driven through mortise wheels 13 feet in diameter, and 24 inches face, by pinions 3 feet 9 inches in diameter, which make 160 revolutions per minute. The pinion shafts were designed to be driven through a wire rope transmission from an engine located 500 feet distant, but are at present driven by the auxiliary engine hereafter mentioned. The rope wheels are 15 feet in diameter, and make 160 revolutions per minute. The engine is 4,700 horse power, and, in addition to driving the pumping machinery, does the hoisting and air compressing for the Calumet mine. In the same building with the mine pumping gearing is a duplicate arrangement for operating the man engines. In order to operate the mine pumps and man engine for the Hecla mine, it was necessary to use rock shafts, which are made of gun iron, and hollow; they are 32 inches in diameter outside, with 4½ inch thickness of metal. The pump rock shaft is 39 feet 4½ inches long over all, in two sections, and weighs 40 tons. There are rockers placed on each end of the shaft, one of which is connected with a crank on the mortise wheel shaft, and the other with the surface rods that work the pump bobs. These rods are of Norway pine, 13 inches by 12 inches in section, and 1,000 feet long. There are two bobs, one above the other, with axes at right angles, each weighing about 25 tons. The connection from the upper bob to the lower has hemispherical pins and brasses to accommodate vibrations in right-angled planes. The slope of the main pump is 39°, and the machinery has been designed to raise water from 4,000 feet depth. The pumps are of the usual Cornish plunger type, with flap valves. There is an auxiliary engine of the Porter-Allen type, for driving the pumps and the man engines when the main engine is not working. It makes 160 revolutions per minute, the same as the rope wheels. The seeming complication of this arrangement is due to the fact that it had to be adapted to existing works, for increased depths, and put in without interfering with the daily operation of the mine.

The Calumet and Hecla Mining Company has also an extensive pumping plant at their stamp-mills, which are located on the shore of Torch Lake, about 4½ miles from the mine. There are located here three pumping engines, two of which have each a capacity of 20,000,000 gallons per day, and the third 10,000,000 gallons per day. The water is elevated between 50 and 60 feet, and is used for treating the tamped rock. Two of the engines are of the inverted compound beam and fly-wheel type, and the third is a geared

* The first engine at the Brooklyn water works was designed and patented by Mr. Wm. Wright, of Hartford, Conn., and started in 1856 or 1857. It gave a trial duty of about 60,000,000. Subsequently another engine of the same type was put down; and in 1860 a single cylinder, beam and fly-wheel engine was erected at the Brooklyn works, which developed a trial duty of 67,000,000. Subsequently, one of the Wright engines was provided with a fly-wheel, which proved to be an improvement.

† These engines were designed by Mr. Leavitt.—Ed.

* The duty of the Lawrence engines computed on the coal consumed from 1876 to 1883, both years inclusive, averaged 94,966,961 pounds; and on the coal used for pumping, 102,048,251 pounds. At Lynn, the duty on the total coal consumed from 1874 to 1883, both years inclusive, was 88,800,475 pounds; and on the coal used for pumping, 115,308,687 pounds.

* Designed by Mr. Leavitt.—Ed.

pump, which has a horizontal double-acting plunger, 36 inches in diameter by 6 feet stroke, driven from the crank of a spur-wheel shaft.

The spur-wheel is 12 feet diameter, 24 inches face, and contains 96 teeth. The pinion engaging with it has 27 teeth, and is fast on the fly-wheel shaft of a Brown horizontal engine, having a cylinder 18 inches in diameter and stroke of 4 feet. The steam pressure used is 110 pounds per square inch, and the engine has a Bulkley condenser. The pump-valves are annular, of brass faced with rubber, and closed by brass spiral springs. Their external diameter is 6 inches, and the lift is confined to half an inch. There are 91 suction and 91 delivery valves at each end of the pump. The maximum speed of this pump is 36 double strokes per minute.

The largest of the compound engines is named "Ontario," and has a vertical low-pressure cylinder 36 inches in diameter, and an inclined high-pressure cylinder 17½ inches in diameter, the stroke of both being 5 feet. These are inverted over a beam or rocker, and the pistons are connected to opposite ends of the same.

The beam attachment of the main connecting-rod is made to a pin located above and midway between the pins for piston connections. The main center of the beam and the crank-shaft have their pedestals in the same horizontal plane. The throw of the crank is 5 feet. There are two differential plunger-pumps, having upper plungers 20 inches in diameter, and lower plungers 33 inches in diameter, with a stroke of 5 feet. These pumps are vertical, and placed beneath the engine bed-plate, to which they are attached by strong brackets. The pump under the low-pressure cylinder is worked direct from its cross-head by an extension of the piston-rod. The other pump is worked by a trunk connection from the opposite end of the beam. The radius of the beam is but 50 inches, but the connections to it are made very long by links.

The lower plungers work through sleeves in diaphragms located in the center of the pumps. In these diaphragms the openings for the delivery-valves are made. These valves are similar in construction to those previously described for the horizontal plunger-pumps. Their diameter, however, is but 5½ inches instead of 6 inches, and there are 72 suction and 72 delivery valves for each pump. It will readily be seen that the action of these pumps is similar to that of the bucket and plunger, each pump having one suction and deliveries for each revolution of the engine. The "Ontario" is designed to run at a maximum speed of 33 revolutions per minute; and the service required of it is to run regularly 144 hours per week without a stop, which is performed with the utmost regularity.

The differential pump was invented and patented, many years since, by James Ramsden, in Pennsylvania, who designed it for an ordinary house-pump. It was subsequently reinvented by the writer, who first ascertained that he was not the original inventor upon applying for a patent. A pump of this description was run at the Hecla mine for several years, at a speed of 500 feet per minute, and its performance was in every way satisfactory.

DIRECT-ACTING STEAM PUMPS.

This class of pumping machinery deserves a prominent place, as the number in use vastly exceeds those of all other types combined. The first consideration will be given to the Worthington, which is the pioneer of its type, having been invented by the late Henry R. Worthington, and patented in 1844. Mr. Worthington's pump was designed for feeding boilers. His first water works engine was built for the city of Savannah, Ga., and erected in 1854. The second engine, which was the duplicate of the Savannah engine, was erected at the city of Cambridge, Mass., in the year 1856, and was guaranteed to deliver 300,000 gallons in 24 hours to an altitude of 100 feet. It had a high-pressure cylinder 12 inches in diameter, placed within a low-pressure cylinder 25 inches in diameter, the low-pressure piston being annular. The double-acting water-plunger was 14 inches in diameter, and worked direct from the high-pressure piston-rod, the stroke of pistons and plunger being 25 inches. This engine was tested in 1860, with the result of a duty equal to 70,463,750 foot-pounds per 100 pounds of coal. Subsequently a test made by Mr. Frederick Graff, of Philadelphia (long prominently connected with the Philadelphia water department), and the late Erastus W. Smith, of New York, developed a duty of 71,278,486 foot-pounds per 100 pounds of coal, which long remained the best record in the United States. In 1863, Mr. Worthington brought out at Charlestown, Mass., his crowning success, the duplex engine, which fairly deserves to be placed first among the hydraulic inventions of this century. This engine has since been more extensively duplicated for water works purposes than any other, with the possible exception of the Cornish.

Mr. Worthington and his successors had up to 1884 supplied 214 separate water works with 242 engines, having an aggregate daily capacity of 910,000,000 gallons. This is equivalent to upward of 40 per cent. of the estimated capacity of all the water works pumping-engines in America. The duplex engines have been made of capacities varying from 500,000 to 25,000,000 gallons per day. Their action is so smooth and perfect as to excite the admiration of all beholders. Briefly described, the Worthington duplex, as constructed for water works, consists of two horizontal tandem, compound engines, each of which is connected to a double-acting water-plunger by a continuation of the high-pressure piston rod. The high-pressure cylinder is usually secured to the front head of the low-pressure, the latter having two piston-rods passing through long, sleeved stuffing-boxes outside the high-pressure, and keyed to a cross-head, which has also the high-pressure piston and plunger-rod secured to it. The steam and water ends of the machine are connected by turned wrought-iron cradle bars, as they are termed, which make a light and strong connection. From the cross-head suitable links operate bell-cranks, which work two single-acting vertical air-pumps for each engine. These bell-cranks also give motion to the steam-distribution valves, which are slides working over double ports; and the valve for one side (as it is termed), or one engine, strictly speaking, is worked by the bell-crank of the other, which enables an almost constant flow of water to be maintained in the discharge-pipe. The water-valves are simple rubber disks working over brass gratings, and closed by weights or

springs. Mr. Worthington is entitled to the credit of having introduced multiple valves for pumps. The later duplex engines are provided with cut-off valves, independent of the main slides.

While it is not claimed that the ordinary type of Worthington engines are capable of developing the highest duty, their yearly records are excellent, ranging from 50,000,000 to 65,000,000 duty, and trial duties as high as 77,000,000 have been reported. It is claimed for these engines that their moderate first cost, both as regards engine proper, foundations, and buildings, makes them, in the majority of instances, the most economical plant to put down; and some comparisons will be given later which justify this claim.

Among other uses to which the Worthington duplex has been applied with marked success, may be mentioned their oil-line pumps, which force petroleum, under pressure of 1,500 pounds per square inch, from the oil regions of Pennsylvania to tide-water. A number of these engines working up to 400 horse-power are in use for this purpose. They are also largely used for maintaining the pressure in hydraulic accumulators in use in the various steel-works of this country.

Mr. George F. Blake, of Boston, and the late Hon. L. J. Knowles, of Worcester, Mass., were early in the field as inventors and improvers of direct acting pumps, which have been used with decided success for a variety of purposes—thousands being annually manufactured and sold. These pumps are usually single cylinder steam ends and piston pump ends; though, since the expiration of Mr. Worthington's patents, the George F. Blake Manufacturing Company, and several other builders, have built a few compound duplex pumps.

ECONOMY AND DUTY OF PUMPING MACHINERY.

It has been the custom in America, and particularly in the United States, to have expert duty trials, conducted by engineers of acknowledged reputation, whenever new engines were erected at prominent water works. From a number of reports of such trials, I have selected the following as of the leading interest:

A Cornish engine, which was tested at Jersey City, N. J., in 1857, developed a duty of 63,823,300 foot pounds per 100 pounds of coal. In 1860 a rotative engine at Brooklyn developed a duty of 60,140,700 foot pounds per 100 pounds of coal used. For several years a duty of 60,000,000 was rarely exceeded; and it was not until 1873 that a duty approaching that recorded for the trials of the Simpson compound engines in the London water works was obtained. In July of that year, a board, consisting of John C. Hoadly, James B. Francis, and W. E. Worthen, tested the Simpson compound engine, built by Henry G. Morris, of Philadelphia, at the Lowell Water Works, and obtained a duty of 93,092,273 foot pounds per 100 pounds of coal. This trial was fifty-seven hours' duration. In December of the same year, a board, consisting of William E. Worthen, John C. Hoadly, J. P. Kirkwood, Charles Herman, and Joseph P. Davis, tested the compound pumping engine at Lynn, Mass., built by I. P. Morris & Co., of Philadelphia, and obtained a duty of 103,923,215 foot pounds for every 100 pounds of coal fed to the furnace. This trial was of fifty-two hours' duration; and the experts, in making their report to the Lynn Water Commissioners, said, "The duty given by your engine is, so far as we are aware, the highest that has ever been obtained by trial test of any pumping engine in this country."

In May, 1873, a board, consisting of William E. Worthen, Thomas J. Whitman, and Charles Herman, tested the Simpson compound engine at the Milwaukee water works, and obtained a duty of 76,955,720 foot pounds per 100 pounds of coal.

In May, 1876, a board, consisting of William E. Worthen, John C. Hoadly, and Joseph P. Davis, tested the compound engines built by I. P. Morris & Co., of Philadelphia, for the Lawrence (Mass.) Water Works, and obtained a duty of 96,186,979 foot pounds per 100 pounds of coal, with one of the engines running singly, and of 98,361,700 foot pounds for both engines running coupled; the coal per indicated horse power per hour was found to be 1.684 pounds. The duration of the trial of the single engine was fifty-seven hours, and of the engines running coupled thirty-four hours. It was found that the work done in pumps was eighty-one per cent. of the indicated power of the steam cylinders. Subsequently, in July, 1879, Mr. R. H. Buel made a trial of one of the Lawrence pumping engines, and obtained a duty of 111,548,925 foot pounds per 100 pounds of coal; all the coal fed to the furnaces, including wood used for starting fire, being charged to the trial. Previous to this trial, annular, rubber faced pump valves had been substituted for double beat valves; and the efficiency of the pump was found to be 91.64 per cent. of the indicated power in the steam cylinders. The coal per indicated horse power per hour was 1.63 pounds; and the feed water per indicated horse power per hour, 16.48 pounds.

In October, 1878, a board, consisting of Walter H. Sears and Isaac N. Scott, tested the Corliss pumping engine at Pawtucket, R. I., and obtained a duty of 104,357,654 foot pounds per 100 pounds of coal, on the total consumed, including the wood used to start fires (estimated at forty per cent. its weight in coal). This trial extended over a period of two weeks, the running time being ten hours per day. The same parties made a continuous test of twenty-four hours with the same engine, and report a duty of 133,523,060 foot pounds per 100 pounds of coal. A full description of the Pawtucket engine may be found on p. 189, vol. xxviii., *Engineering*. The pumping engines at Lawrence were fully described in *Engineering*, vol. xxix., pp. 18, 19. In April, 1877, Messrs. Moses Lane, Charles H. Haswell, and Henry Warrington tested the Simpson compound engines at the West Side Water Works, Chicago, built by the Quintard Iron Works, of New York, and obtained a duty of 90,066,800 foot pounds per 100 pounds of coal.

In May, 1882, Mr. Samuel M. Gray, City Engineer of Providence, made a six days' test of the Corliss engines at the Pottaconset Water Works in Providence, and obtained a duty of 113,371,000 foot pounds per 100 pounds of coal, reckoned on the coal consumed, including the wood used in starting fires (estimated at forty per cent. its weight in coal). The average running time for the six days was twelve hours twenty-seven and a half minutes. Deducting the coal used for starting and banking fires, Mr. Gray estimated the

duty at 138,035,000 foot pounds per 100 pounds of coal consumed in running time.

The pumping machinery of the Boston Main Drainage Works consists of a pair of high duty engines and two lower duty engines, the former for continuous, the latter for intermittent service. The high duty engines* were built by the Quintard Iron Works, of New York, at a cost of \$115,000. They are compound beam and fly-wheel engines, working single acting plunger pumps. The cylinders are vertical and inverted, connected with pumps in the same line. Care was taken in designing them to avoid concentration of weight on foundations, to secure great strength in details, large wearing surfaces, and accessibility of parts for examination, repair, or removal, special adaptation of pumps to their peculiar work and great economy in consumption of steam and of fuel.

The steam cylinders are 25½ and 33 inches respectively in diameter; stroke of piston, 9 feet. The pump plunger is 48 inches in diameter and the same stroke as the piston. The crank is of 4 feet radius. The fly-wheel weighs 36 tons. At eleven strokes per minute the engine delivers 25,000,000 gallons a day. Steam is carried at 100 pounds pressure, and moderately superheated.

Two duty trials of these engines, of twenty-four hours' length each, gave 125,000,000 and 122,000,000 foot pounds for 100 pounds coal, no deduction being made for ashes or clinkers. In the first trial the feed pump was driven by a separate boiler.

It may not be amiss, in concluding this paper, to sketch rapidly the leading improvements made in pumping machinery during the past 40 years, and to summarize the characteristics of the best.

The most important improvement in heavy steam pumping machinery has been in compounding, which has conduced to both economy of fuel and smoothness of action, and has reduced to a very great extent wear and tear. In the pumps the substitution of multiple valves for the enormous clacks, and double, treble, or four beat valves formerly used, has proved of very great advantage. Improvement in design, in the direction of making the parts of greater strength and massiveness, as well as more accessible for examination and repair, has been decided. Automatic valve gears, controlled by a governor, are now largely adopted. High pressure steam, and high grades of expansion, came in, as a matter of course, with compounding. Mr. Corliss, in his practice, has reached 125 to 130 pounds boiler pressure, expanded 20 times; while in the new Louisville engine, it is proposed to work under 140 to 150 pounds.

By far the most important improvement has been in the introduction of direct-acting steam-pumps, either simple or compound. They are an established article of manufacture, kept in stock, and made with interchangeable parts, to standard jigs and templates. Their economy of first cost and portability strongly commend them for general use.

For small water works, and for large works where the cost of fuel is not great, the compound Worthington duplex engine possesses very great advantages, owing to its small first cost and good average running economy. Including foundations and structures, these engines cost less than half that of first class compound beam and fly-wheel engines of equal capacity. In fact, at the Boston sewage works, their cost, as estimated by the writer, does not exceed 40 per cent.; and, with cheap coal, the saving by the high duty fly-wheel engine will barely pay interest on its extra cost. At the Lowell water works, there is a Simpson compound engine, which would probably cost \$75,000 to duplicate at the present time. By its side stands a Worthington duplex, whose cost at present prices would not exceed \$25,000. The duty of the Simpson engine for 1883, on the total coal consumed, was in round numbers 78,000,000, and of the duplex engine 61,000,000. The Worthington engine would have required 198 tons more coal to have done the work actually credited to the compound fly-wheel engine, which would cost, at \$5 per ton, \$990, which is 1.9 per cent. interest on the \$50,000 extra cost of the fly-wheel engine. It is fair to state that the beam and fly-wheel engine was not working up to its full capacity, though rather above one-half. Doubling the work done would require 396 tons more coal, worth \$1,980 for the duplex engine, which is equal to about 3.8 per cent. on the extra cost of the fly-wheel engine.

A more important comparison is afforded by the West Side water works at Chicago, which have cost, including machinery, buildings, and foundations, not far from \$650,000. A duplex plant of the same capacity could easily be supplied complete for \$300,000. The cost of fuel per million gallons, pumped at the West Side works in 1883, was \$1.90; the amount pumped being 10,000,000,000 gallons, with two engines. The four engines can pump 20,000,000,000 gallons, which at \$1.90 per million would cost \$38,000. To pump this quantity of water with duplex engines would require not exceeding one-third more fuel, costing \$12,067.67, which is equal to 3.62 per cent. interest on the extra actual cost of the plant in use. In the selection of cases for comparison, plants which are acknowledged to be first class have been chosen.

The firm of Henry R. Worthington have built and put in operation at their works in Brooklyn, a high-duty engine, whose performance rivals that of the best compound fly-wheel engine, as will be seen by reading the report of the trials made by Mr. John G. Mair, Managing Partner of Simpson & Co., London, and his assistant, Mr. Henry Smith, which indicate a gain over the unimproved engine of about sixty per cent. A duty exceeding 100,000,000 has been reached by an engine of less than 100 H. P.

From what has been said, it will be seen that "high duty" may cost too much. Its value must be predicated on the saving of fuel, as balanced by the interest and depreciation account of the extra expenditure for plant. If the saving tips the scale, high duty is a good investment; otherwise, not.

Among the most successful examples of high duty pumping engines, commercially considered, that have come under the writer's notice, are those at Pawtucket and Providence, R. I., and Lynn, Mass.; in all of which instances, comparatively small engines, of moderate first cost, are made to do large amount of work by means of high pressure steam and high piston speed. The key to establish success appears to be the adoption of these twin adjuncts to economy.

* Designed by Mr. Leavitt.—Ed.

OLIVER EVANS AND HIS INVENTIONS.*

By COLEMAN SELLERS, JR.

Of all the early American mechanics, there is perhaps none who has left a more definite impress upon the industrial progress of our country than Oliver Evans, and there is none whose successes and failures are of more interest to the student of mechanical history. He is widely recognized as the inventor of improvements which completely revolutionized the processes of flour manufacture, and which remain in use to-day substantially as he left them.

But it is not alone as an inventor of flour making machinery that he claims our attention; he is even more widely known for his earnest and successful efforts to introduce the high pressure steam engine, and by his enthusiastic advocacy of steam locomotion. Indeed, he has been styled the "Father of the High Pressure Steam Engine," and it has been often said that he was the original projector of the locomotive, and the inventor of the first practicable steamboat. These broad claims have generally been maintained by American writers and ignored by the English, who give much the same credit to Richard Trevithick, Oliver Evans' contemporary.

It is, of course, difficult in any such case to clearly establish general claims to priority in the conception of ideas; but we can, at least, compare his work with that of other inventors of his time, and form some judgment as to their relative merits. With this in view, it will be our task this evening to review briefly the life and labors of Oliver Evans; to acquire, if we can, a just appreciation of the true value of his work and his proper place among those geniuses to whom we owe the mechanical attainments of the present age; to learn, if we may, who and what he was, and what his environment; to learn the meagerness of his opportunities, the restrictions by which he was hampered, that we may the better understand the character and value of his inventions, and the measure of credit to which he was entitled.

Unfortunately, what is recorded of his life can be told in a few words, and is, indeed, little more than a history of his work. He was born near Newport, Del., in 1755, and died in New York city, in 1819.

When he was born, our country showed scarcely a trace of its present industrial development. The Atlantic seaboard was sparsely settled throughout its length, and a few adventurous pioneers were forming occasional settlements beyond the Alleghenies. Not only were there no railroads and no canals, but there were no tolerable highways of any kind except in the neighborhood of the larger towns. The goods required by the settler on the Ohio or Lake Erie were packed on horseback over the mountains, through Pennsylvania, by Lancaster and Chambersburg, or by the Southern route through Virginia, by Winchester, Hagerstown, and Cumberland. It was not until 1789 that the first wagon load was sent over the Southern route to the shores of the Ohio. These four-horse wagons would haul twenty hundredweight from Hagerstown to Pittsburgh and back in about a month, and charge \$3 a hundredweight for hauling. Salt, packed over the mountains, sold in Pittsburgh for \$8 a bushel as late as 1796, when salt from Western New York was introduced at half that cost.†

When Oliver Evans was born, there was just one steam engine on the American continent; before he died, steam engines were in common use. During his life, good turnpikes were completed, canals projected and partly built, and steamboat navigation established on the great rivers. These were vast strides; but the crowning achievement, the railroad, which his prophetic eye discerned so clearly, he did not live to see an accomplished fact.

Evans was apprenticed at the age of fourteen to a wheelwright. He was a thoughtful, studious boy, who devoured eagerly the few books to which he had access, even by the light of a fire of shavings, when denied a candle by his parsimonious master. He says that in 1772, when only seventeen years old, he began to contrive some method of propelling land carriages by other means than animal power; and that he thought of a variety of devices, such as using the force of the wind and treadles worked by men; but as they were evidently inadequate, was about to give up the problem as unsolvable for want of a suitable source of power, when he heard that some neighboring blacksmith's boys had stopped up the touch-hole of a gun barrel, put in some water, rammed down a tight wad, and putting the breech into the smith's fire, the gun had discharged itself with a report like that of gunpowder. This immediately suggested to his fertile mind a new source of power, and he labored long to apply it, but without success, until there fell into his hands a book describing the old atmospheric steam engine of Newcomen; and he was at once struck with the fact that steam was only used to produce a vacuum, while to him it seemed clear that the elastic power of the steam, if applied directly to moving the piston, would be far more efficient.

He soon satisfied himself that he could make steam wagons, but could convince no one else of this possibility. At the age of twenty-two, he had completed a successful machine for making the wire teeth of wool cards, and then invented, but did not build, a machine for making and sticking the teeth in the leather backs. In 1780, he married the daughter of John Tomlinson, a Delaware farmer, and removed to Queen Anne County, Md., where he opened a store. Here he seems to have remained until 1783, when his two brothers, who were practical millers, persuaded him to join them in building a merchant flour mill in Newcastle County, Del. They started the mill September 5, 1785, and it required the constant attention of three men with "half the time of a boy." Evans was disgusted with the crude and laborious methods then in use, and worked out a system of mechanical devices which could replace the labor of the attendants.

In the old mill, the wheat or meal was handled at

each stage of manufacture, and was carried from one point or one machine to another by manual labor. This he entirely revolutionized, and when he had applied his improvements, he found that the mill, which formerly required more attention than three men could give, was easily managed by one man; indeed, Evans wrote that once, when a committee of millers came to see his new machinery, he took care to be at work in a neighboring hay field. They found the mill open and at work; and walking over it, they saw that all the operations of milling were going on without the care of any attendant—cleaning, grinding, and bolting all in progress without human intervention. This, Evans thought, would be convincing, but they returned home and reported the whole contrivance "a set of rattletraps unworthy the attention of men of common sense."

Having worked out his improved system and demonstrated its practical value, he set about putting it into general use. This he proposed to do by selling "rights" to millers; and he and his brothers canvassed Maryland, Pennsylvania, Delaware, and Virginia without success, although they offered the right free to the first miller in any county who would put in the improvements. The greatest obstacle to his success was the obstinacy of the millers of the Brandywine, whose mills were the most celebrated in the country. They declined to put in his machinery on any reasonable terms, although he had shown them what it appears should have been a convincing proof of the value and utility of his improvements.

Oliver Evans was one of those discontented men who are not satisfied to do things in the time-honored but perhaps clumsy way in which they have always been done, and constantly sought opportunities to improve existing methods, and I fancy he generally found them. Certainly, the flour mill of the period badly needed mechanical assistance.

Thomas Ellicott, who helped Evans in the preparation of his "Millwright and Miller's Guide," in 1795, wrote that when he first began the business (about 1757), "Mills were at a low ebb in this country, neither burr-stones nor rolling screens being used; and but few of the best merchant mills had a fan. Many carried the meal on their backs, and bolted it by hand even for merchant work; . . . it was counted extraordinary when they got their bolting to go by water; after fans by hand, and standing screens; then burr-stones, rolling screens, and superfine bolting cloths with a number of other improvements, some of the latest are the elevators, hopper-boys, etc., invented by Oliver Evans, late of Delaware, though now of Philadelphia. . . . By them the manufacture of grain into flour is carried on by water, with very little hand labor and much less waste, either in small or large business. And I do believe, that taking a large quantity of wheat together, that we can make two or three pounds more out of a bushel by the new than by the old way, although it be equally well ground; because it is so much more completely bolted, and with less waste."

"In the old way, the wheat is weighed and carried up one or two pairs of stairs, and thrown into garners; the bags often having holes in, it is spilt and trampled under foot; several pounds being frequently lost in receiving a small quantity, and when it is taken from these garners, and carried to the rolling screens, some is again wasted, and as it is ground it is shoveled into tubs, a dust is raised, and some spilt and trampled on; it is then hoisted and spread, and tossed about with shovels, over a large floor, raked and turned to cool, and shoveled up again and put into the bolting hopper; all which occasions great labor, besides being spilt and trampled over the mill, which occasions a considerable waste. Besides these disadvantages, there are others in attending the bolting hoppers; being often let run empty, then filled too hard, so that they choke, which occasions the flour to be very unevenly bolted; sometimes too poor, and at other times too rich, which is a considerable loss; and when the flour is bolted, it is much finer at the head than the tail of the cloths; the fine goes through first, and has to be mixed by hand, with shovels or rakes; and this labor is often neglected or only half done; by this means, part of the flour will be condemned for being too poor and the rest be above the standard quality. The hoisting of the tail flour, mixing it with bran by hand and bolting it over, is attended with so much labor that it is seldom done to perfection."

It thus appears that the improvements in milling which were originated by Evans were chiefly in devices for handling the grain and its products during the processes of manufacture without the employment of manual labor. These devices were of various kinds, adapted to the nature of the service they were to perform, and in his publications Evans claimed five different ones, viz., the elevator, for raising vertically; the descender, transferring down an incline; the conveyor and the drill, for moving horizontally; and the hopper-boy, whose function was to spread and cool the meal and feed it regularly into the bolting hopper. The elevator, perhaps the most important of these, was a modification of one of the oldest of machines, the "chain of pots," which had been used for raising water from time immemorial. As modified for raising grain, it was constructed of an endless flat band or strap, carried upon two drums or pulleys, and upon which, at regular intervals, a number of small troughs or buckets were so arranged that in passing under the lower pulley the buckets filled, and in passing over the upper one emptied themselves into a suitable box, from which a spout discharged the contents as required, the apparatus being kept in motion by power applied to the upper pulley. This machine has been vastly increased in size and capacity since Oliver Evans first put it to work in his little New Castle mill, and it is now applied to a multitude of uses that were never contemplated by him; but the device is essentially the same, and has proved itself to be one of the most useful of his inventions. The descender he himself described as "a broad, endless strap, of very thin, pliant leather, canvas, or flannel, etc., revolving over two pulleys, which turn on small pivots, in a case or trough, to prevent waste, one end of which is to be lower than the other. The grain or meal falls from the elevator on the upper strap, and by its gravity and fall sets the machine in motion and discharges the load over the lower pulley. There are two small buckets to bring up what may spill or fall off the strap and lodge in the bottom of the case." Although this machine would

work by gravity, even when the descent was small, yet Evans recommended that power should be applied to it where practicable; and when driven in this way it became the prototype of the belt conveyors of the present day, which are generally used for the horizontal movement of grain in large quantities. Concave carrying rollers, or other devices, are now employed to compel the belt to form a trough which will hold a greater amount of grain than would stay on a flat belt. Evans also used for the same purpose the drill, which was simply an elevator laid horizontally, with wooden cleats, or, as he called them, "rakes," instead of buckets. These rakes scraped the grain along the bottom of the case or box in which they ran. The conveyor was simply a quick pitch screw of two or more threads, running in a trough or box into which it fitted closely. This screw, when used for grain, Evans made of a round wooden shaft, around which he nailed two or more sheet iron helices, or spirals, which, when the shaft was rotated, forced the grain along in the trough. When he desired to move flour or meal, he substituted for the sheet metal helix a number of radial arms, arranged spirally around an octagonal shaft.

The hopper-boy consisted of a slowly rotating vertical shaft, or spindle, the lower end of which passed through a horizontal beam, upon whose lower surface were arranged a number of inclined boards called "flights," whose function was to spread the meal and to gather it toward the bolting hopper. The horizontal arm also carried a "sweeper," or scraper, which pushed the meal into the hoppers, which were situated in the floor near the base of the vertical post. The meal was allowed to fall from the elevator at the extremity of the arm, which carried on each end an adjustable scraper, whose function was to drive the meal before it, trailing it in a circle, so as to discharge its load by the time it again reached the elevator. This circle of meal was collected by the "flights" and forced into the hoppers as described. The first flight, or that next to the scraper, could be swiveled so as to pile the meal in a ring to allow it more time to cool. As this ring increased in thickness, the arm rose on the spindle to suit. This was rendered easier by the fact that it was counterweighted over a pulley near the top of the spindle. The arm fitted loosely to the spindle, and was provided with an upper bearing of iron, by means of which it could be leveled, and it was driven by means of a rope from a cross-beam near the top of the spindle. In order to deflect the grain delivered from an elevator in any particular bin, Evans used a pivoted wooden spout which could be rotated to suit his needs. All of these devices were efficient means of accomplishing the end in view, and were all of such a simple character that they could be readily constructed by the mill-wright with ordinary tools and materials.

At this time the U. S. Patent Office had not been organized, and the several States exercised the privilege of granting exclusive rights to the use of inventions within their own boundaries. In 1786, Evans applied to the Legislature of Pennsylvania for a right to use his improvements in machinery for making flour, and also to use his steam wagons on the roads of the State. During this year he explained his proposed engine to several people, and in particular his plan for propelling boats by paddle-wheels turned by steam engines. The following year the Legislature granted his flour mill patent, but made no allusion to the steam wagon claim; but on May 31, the Legislature of Maryland granted both rights for fourteen years, on the ground that although it would doubtless do no good, yet it certainly could do no harm. A similar patent was subsequently granted (1789) by New Hampshire.

About this time, the Ellicotts, well-known millers on the Patuxent, in Maryland, adopted Evans' improvements with great success, so that in making about 325 barrels of flour daily, they saved annually in wages \$4,875, and increased the percentage of flour obtained from the wheat so as to reduce the cost of flour fifty cents per barrel, which amounted, Evans says, to a total saving of \$32,500 yearly. In 1790, when the U. S. Patent Office was organized, Evans relinquished his State rights, and December 18, 1790, a U. S. patent was granted for his "method of manufacturing flour and meal." This is said to be one of the three patents granted that year. In 1794, he arranged with a Mr. Joseph Stacey Sampson, of Boston, to introduce and patent his steam engine improvements in England, and he furnished him with full drawings and specifications for this purpose. It is said that Mr. Sampson showed these papers to many English engineers, but that he died in England without having done anything to further Evans' interest.

Some time previous to 1790, Evans had removed to Philadelphia, and soon began the preparation of the *Millwright and Miller's Guide*, which appeared in 1795. This book took three years to prepare, during which time he exhausted his capital, injured his eyes, and became gray. The first edition was of 2,000 copies, was published by subscription, and sold for \$3 each to subscribers. He says that during this time his wife sold tow cloth of her own make to help feed their large family. In 1800 he had a mill about Third and Market Streets, and the next year was selling mill supplies at the southeast corner of Ninth and Market Streets.

Having tried in vain to induce some one to advance him the necessary capital to build an experimental traction engine, he began the work in 1801, on his own responsibility, being moved thereto, he says, by sense of his obligations to the State of Maryland, which had granted him a patent, when all others scouted at his visionary scheme. Before he had completed his engine he concluded that as it differed from any of those then in use, it might be worth while to make some other application of it. He, therefore, changed his plans and started a small stationary engine, 6-inch cylinder, 18-inch stroke, which he had running in the winter of 1802, on Market Street. He set it to grinding and breaking plaster of Paris, then recently introduced as a fertilizer, and it broke and ground twelve tons in twenty-four hours; or when applied to sawing, with twelve saws, it cut up 100 feet of marble in twelve hours. This little engine and boiler cost him \$3,700, including his own time, which he valued at \$1,000. It took all his capital, and again, he tells us, he was impoverished.

The success of this little engine led to an order for one to drive a steamboat on the Mississippi. The boat was built 80x18 feet, at New Orleans, where Evans sent the engine. A freshet, however, left the boat stranded far from the river's edge, and while awaiting another rise to get her off again, the engine was removed and

* Abstract of a lecture delivered at the Franklin Institute, November 30, 1885.

† The writer desires to express his indebtedness for illustrations used in this lecture, to President Henry Morton, Stevens Institute of Technology, for lantern slide of the "Stevens Engine;" to Prof. Geo. F. Barker, of the University of Pennsylvania, for slides showing types of early locomotives; to Prof. Benjamin Sharp, also of the University, for transparency of Oliver Evans' portrait; and to Robert C. Davis, Esq., for information furnished and engraving loaned.—C. S., Jr.

† Bishop's "History of American Manufactures."

set to sawing lumber. This it did at the rate of 3,000 feet in twelve hours, which sold for \$60 a 1,000, and in this time burned a cord and a half of fuel. It is worthy of remark that this engine ran for a year without failure of any sort. An incendiary fire, attributed to the hand sawyers, whose business was injured by the engine, destroyed the mill, and the engine lay idle for nearly ten years, when it was again put to work, this time driving a cotton press. The boat and engine involved a loss of \$15,000 to the enterprising owners.

In 1803 Evans started in business as a regular engine builder, and he was probably the first in the United States to make a specialty of this work. The Philadelphia Board of Health ordered of Evans, in 1804, a steam dredging machine for cleansing the docks of the city. This machine he called the "Oruktor Amphibolos," or Amphibious Digger, and he described the craft and its performances as follows: "It consists of a heavy flat-bottomed boat, 30 feet long and 12 feet broad, with a chain of buckets to bring up the mud, and hooks to clear away sticks, stones, and other obstacles. These buckets are wrought by a small steam engine set in the boat, the cylinder of which is five inches diameter, and the length of stroke 19 inches. This machine was constructed at my shop, one and one-half miles from the river Schuylkill, where she was launched. She sunk nineteen inches, displacing 531 cubic feet of water, which at 92.5 pounds, the weight of a cubic foot, gives the weight of the boat 34,437 pounds, which divided by 213, the weight of a barrel of flour, gives the weight of 161 barrels of flour that boat and engine are equal to. Add to this the heavy pieces of timber and wheels used in transporting her, and the number of persons generally in her, will make the whole burden equal to at least 300 barrels of flour. Yet this small engine moved so great a burden with a gentle motion up Market Street and around the Center Square; and we concluded from the experiment that the engine was able to rise any ascent allowed by law on turnpike roads, which is not more than four degrees.

"Before launching, July, 1805, this machine was run during several days around Center Square, and the daily papers of that time contain an advertisement by Evans, in which he invited those interested to visit the square and inspect the Oruktor Amphibolos; he also mentioned that twenty-five cents apiece would be collected from those of the spectators who felt disposed to contribute it, and said that one-half of the sum thus realized he proposed to retain himself, and promised to expend it in the prosecution of other useful inventions; the remaining half of this money he proposed to divide among his workmen, who, he further said, at their own expense provided the wheels and axles upon which the scow was mounted, those first made having failed on account of their inability to support the great weight put upon them. Finally the scow was launched at Market Street Wharf; the engine having been connected with the paddle wheel, she steamed down the Schuylkill and up the Delaware to her dock."

Having satisfied himself that he could build a traction engine, he made, September 26, 1804, a statement to the managers of the Philadelphia and Lancaster Turnpike Company, in which he set forth the comparative expense of hauling by steam and horse power, and showed conclusively, in his estimation, that by adopting his proposed engines they could nearly treble the net profits they made with the Conestoga wagons. He proposed that this traction engine should carry one hundred barrels of flour, travel three miles per hour on a level road, and one mile an hour up and down hills, and it was to make the trip to Columbia in forty-eight hours; while to carry the same load in the usual way took five wagons, with five horses each, seventy-three hours. No attention seems to have been paid to this document, and in December of the same year we find him petitioning Congress to extend the term of his flour mill patents. The bill passed safely to a third reading, when an unexpected opposition arose which caused its defeat. While anticipating the favorable action of Congress, Evans advertised a new book, to be entitled "The Young Engineer's Guide," upon which he proposed to expend \$3,000, and produce a very exhaustive and valuable work. Completely disheartened by the failure of his bill, and deprived of the additional royalties he felt sure of getting, he was obliged to issue a much smaller book than he had intended, and to omit many of the illustrations which he had promised. This abridged volume he called "The Abortion of the Young Engineer's Guide."

Evans expected great things from the extension of his patents, for, although his royalties had been very low, yet comparatively few millers adopted his inventions while the first patents were in force. After their expiration, the millers hastened to avail themselves of the advantages offered by his improvements, and when, in 1808, Congress finally passed a bill continuing his patent rights for twenty-two years, and protecting him for the interval between the expiration of his first patents and the date of the regrant, Evans felt that better days had at last dawned upon him. He put up prices from \$30 for one pair of four and one-half feet stones to \$300, and from \$200 for five pairs of seven-foot stones to \$3,675; but no great success appears to have attended this move, for whereas some mill-owners, Thomas Jefferson, for instance, paid the license, most of them refused, and were only compelled by process of law, which involved the inventor in a series of expensive and troublesome litigations. It is probable, however, that from this time his circumstances were somewhat more comfortable.

In 1808, Mr. B. H. Latrobe, in his report to the American Philosophical Society, describes five or six engines then at work in the United States, and, among others, mentions "a small engine erected by Mr. Oliver Evans." This was, doubtless, his first engine, that which he started the year previous to Mr. Latrobe's report.

In 1807, he established the Mars Works, at the corner of Ninth and Vine Streets, Philadelphia, and announced himself as an iron founder and steam engineer. This business he carried on until his death. In 1810, he associated with him his sons-in-law, James I. Rush and David P. Muhlenberg, and shortly afterward they purchased the lot at the corner of Sixteenth and Buttonwood Streets, which is now occupied by a portion of Mr. James Moore's Bush Hill Iron Works.

In 1812, he mentions ten of his engines as being then in use, and four years later he claims fifty. In 1817, he received an order for an engine and boilers for the Fairmount Water Works. This engine had a 30 inch

cylinder, 5 foot stroke, and was started in December of that year. It was supplied by four cast-iron boilers, 30 inch diameter, 24 feet long, carrying steam at pressures ranging from 194 to 230 pounds per square inch. Its product was 3,072,606 ale gallons, pumped 103 feet high in twenty-four hours, at an expenditure of 1,680 cubic feet of wood. It does not appear to have been an entire success, and the boilers burst on three different occasions.

Evans seized every opportunity to press his claims for the high pressure engine. He set forth his views at some length in "The Abortion of the Young Engineer's Guide," in 1805, describing his engine and its application to various duties, gave rules for pressure and point of "cut-off," and recommended a cylindrical boiler, 3 feet diameter, with a maximum length of from 20 to 30 feet. In this work he republished some of his previous papers, and also the acrimonious correspondence carried on in the *Repository* between himself and Col. Stevens, of Hoboken, N. J., in which he accused the latter of appropriating his ideas. In this work, Evans also described his projected volcanic steam engine, in which the products of combustion were to be passed into the water to assist in vaporizing it; and he also set forth a scheme of mechanical refrigeration.

In the *Emporium of the Arts and Sciences*, vol. ii., published in Carlisle, Pa., 1812, we find quite an extended account of the state of the steam engine at that period, and the feeling against the use of high pressure steam is well illustrated by an account of the explosion of one of Trevithick's boilers with fatal effect. This fear of the power of high pressure steam dated from the time of Watt, who thought Richard Trevithick ought to have been hanged for using it, and was a potent factor in the opposition which Evans encountered in his efforts to introduce his engine. In the *Emporium*, he gave an account of his "Columbian Condensing High Pressure Steam Engine," somewhat modified from that shown in his earlier publications; he also described the progress of his invention, and reiterated his offer to make a steam carriage that would "run on good level railways" at the rate of fifteen miles an hour; and repeated his oft-quoted prophecy as to the future of the railroad.

Evans again appeared in print in 1815, when he published an address to the people of the United States, in which he offered the use of his patented improvements in steam engines for propelling boats or land carriages upon liberal terms to any who would form companies for the purposes of using them. In 1816, he published "An Exposition of Part of the Patent Law by a Native Born Citizen of the United States, to which is added Reflections on the Patent Laws." During his struggle to secure from Congress an extension of his patent rights, Evans issued a pamphlet entitled "Oliver Evans to His Counsel, who are Engaged in the Defense of His Patent Rights for the Improvements He has Invented, Containing a Short Account of Two out of Eighty of His Inventions, their Use and Progress in Despite of All Opposition and Difficulty, and Two of his Patents with Explanations."

The "drawings and specifications" of the eighty inventions mentioned in this formidable title were ruthlessly committed to the flames in the presence of his assembled family, while he was suffering under the mortification caused by the defeat of his application to Congress; and there is every reason to believe that he ever afterward sincerely regretted this foolish act.

In April, 1819, Evans was visiting in New York city, when he received the distressing information that his Philadelphia shop had been destroyed by an incendiary fire. This news appears to have brought on a fatal attack of apoplexy, and he died on the twenty-first of the month. Thus ended in a new and bitter disappointment the life of one whose existence seems to have been one long struggle against the incredulity and prejudice of those whom he sought to benefit. He lacked the capital to carry out his cherished schemes, and keenly felt the apathy which prevented the accomplishment of his great purposes.

His life, though full of disappointments, was not without its compensations; the success of his steam engine was itself a triumph and a vindication, and the universal adoption of his mill improvements afforded him more or less remuneration, and increased his business as a millwright and engineer. In regard to these improvements, there can scarcely be two opinions; his own testimony is amply supported by contemporary evidence that is unassailable. His theories of physics, especially of thermo-dynamics, were doubtless, many of them, faulty enough, as might be expected from one whose scientific knowledge was so scanty, and whose books were so few; but his mechanical ideas were seldom at fault, and his constructions were the best that his opportunities afforded. His application of the ancient chain of pots to lifting solids was a most felicitous conception, and has found its way into many other branches of industry not contemplated by him.

His system of handling grain, modified in detail only, in principle the same as he left it, is now used in all our flour mills, in all of the grain elevators which mark the railroad stations in our great Western wheat country, and the vast granaries of the railroad termini, with their capacity for holding millions of bushels; this system handles every grain of wheat, from the time it leaves the wagon of the Western farmer until it is packed as flour in some gigantic Minneapolis mill, or stored in the hold of the transatlantic steamer.

With regard to Oliver Evans' connection with the steam engine, this much we can safely say, that he

"The time will come when people will travel in stages, moved by steam engines, from one city to another almost as fast as birds fly—fifteen to twenty miles an hour. Passing through the air with such velocity, changing the scenes in such rapid succession, will be the most exhilarating, delightful exercise. A carriage will set out from Washington in the morning, and the passengers will breakfast at Baltimore, dine at Philadelphia, and sup at New York the same day."

"To accomplish this, two sets of railways will be laid so nearly level as not in any place to deviate more than two degrees from a horizontal line, made of wood or iron, on smooth paths of broken stone or gravel, with a rail to guide the carriages so that they may pass each other in different directions and travel by night as well as by day; and the passengers will sleep in these stages as comfortably as they do now in steam stage-boats. A steam engine that will consume from one-quarter to one-half a cord of wood will drive a carriage, 180 miles in twelve hours, with twenty or thirty passengers, and will not consume six gallons of water. The carriages will not be overladen with fuel or water. . . . And it shall come to pass that the memory of those sordid and wicked wretches who oppose such improvements will be execrated by every good man, as they ought to be now."

"Posterity will not be able to discover why the Legislature or Congress did not grant the inventor such protection as might have enabled him to put in operation those great improvements sooner—he having asked neither money nor a monopoly of any existing thing."—*Extract from Address to the People of the United States.*

early conceived the idea of using steam of high pressure, that he lost no opportunity to bring his views to the attention of those whom he thought could assist him in the realization of his hopes; that he built a successful steam engine in 1802; drove a heavy wagon by steam in 1803, and propelled a boat by steam-driven paddle-wheels the same year; that the type of engines he designed (small diameter of cylinder and long stroke) continued for many years the distinctive American engine. We see that he helped to overcome, by his personal exertions, the universal fear of high pressure steam, and introduced a type of engines which, by their lightness and cheapness, were fitted for the needs of a new settlement. But that he was the first man to conceive of the idea of using high pressure steam is scarcely probable; that he originated the locomotive is very doubtful.

A Frenchman named Cugnot built a model high pressure traction engine in 1769, which ran for a time about the streets of Paris, until it upset, and was, with its inventor, promptly cast into prison. The next year he made a second, which is still in existence in Paris, and failed chiefly because its boiler was too small. In 1784, Murdoch made a model high-pressure engine, and Watt in his patent put forth the idea of a steam carriage for common roads. This was two years before Evans applied for his patent in Pennsylvania. In 1800, Trevithick made an engine with beam, cylinder 19 inches diameter, 5 feet stroke, and in 1802 he took out his patents.

There are certainly many points of similarity between the engines of Trevithick and Evans, but I do not think it is proved that the former copied the drawings of the latter, or even appropriated his ideas. It is much more likely that the two inventors, having the same goal before them, endeavored to arrive at it by the same means, or, as Oliver Evans says of another, "it frequently happens that two persons, reasoning right on a mechanical subject, think alike and invent the same thing without any communication with each other."

We can afford to grant a measure of merit to Evans' contemporaries without injuring his memory. He accomplished enough to establish his reputation upon a firm basis. What he might have done with better facilities and ample capital we can scarcely conjecture. My own opinion is that he underestimated the difficulty of building such a traction engine as he conceived possible; and from the fact that such engines are only now coming into anything like common use in this country, I fear that had he been permitted to carry out his ideas, the result would have fallen far short of his cherished expectations. We cannot but admire the pluck and determination with which he endeavored to develop his inventions, the courage with which he expressed his convictions. In the words of the late Mr. Joseph Harrison, Jr.: "He, with no misgivings as to the future, and with no dimmed vision, saw with prophetic eyes all that we now see. To him the present picture, in all its grandeur and importance, glowed in broad sunlight."

And as was said by another: "Wherever the steam mill resounds with the hum of industry whether grinding flour on . . . the Schuylkill, or cutting logs in Oregon, there you find a monument to the memory of Oliver Evans."—*J. F. I.*

THE TRANSFORMATION OF HEAT INTO ELECTRICAL ENERGY WITH BATTERIES, THERMOPILES, AND DYNAMO MACHINES.*

WITH batteries, it is the heat generated by the chemical processes going on in them which is transformed into electricity. With thermopiles, there is a direct transformation of heat into electricity. With dynamos, it is work that is transformed into electricity, and this work is usually done by a steam or some form of gas engine.

In a battery the heat used is the difference of the heat evolved and absorbed in the various chemical actions which go on in it.

Thus, taking a Daniell battery, we have the heat given out in the formation of zinc sulphate minus that absorbed in the decomposition of the electro-chemically equivalent amount of copper sulphate, or, what is the same thing, the heat given out in the union of zinc with oxygen minus that given out by the union of copper with oxygen.

We will consider as the available heat only that which is generated outside the battery. Thus, if we consume a certain amount of material in the battery, a certain part of the heat goes to warm the battery itself, owing to its resistance, and this heat is lost, and cannot be made to do external work. Thus, if the current be A amperes, and the resistance of the battery R ohms, the work which goes to heat it per sec. is A^2R ; and if E be the E.M.F. of the battery, the work which is done outside the battery per sec. is $AE - A^2R$. Now, $A = \frac{E - e}{R + R'}$, where e is the E.M.F. generated by the motion and R' the resistance of the external circuit. The ratio of the heat used in the external circuit to the whole heat given out by the battery, if we do not take into account local action and other causes of waste in the battery, is $\frac{AE - A^2R}{AE}$, or, substituting the above value of A ,

$$\frac{E(R + R') - e^2}{E(R + R')^2} \quad \text{If } R = R', \text{ this becomes } \frac{E + e}{2E}.$$

This last ratio is greatest when $e = E$. Then all the heat is used outside the battery; but then there is no current. We see from this that we may increase the ratio of the heat given out in the external circuit to that used in battery by increasing either R' or e ; and that theoretically we may use very nearly the whole heat externally. The same reasoning applies to thermopiles and dynamos. In practice, however, there are other things to be taken into consideration. For particular practical cases, taking into account the actual material used up, the author gives the percentage 47.73 for a Daniell and 59.1 for a Bunsen.

In the case of thermopiles, the percentage of heat available in the circuit is very small indeed. There we count as the heat employed the heat given out by the fuel actually burnt. For a pile of Rebeck, from data given by Herr Kayser in *Wied. Ann.*, only 0.16 per cent.

* Abstract from an article by Wilhelm Poukert in the *Zeitschrift für Elektrotechnik—Electrician*.

of the heat. This was for 20 or 25 elements. For 50 large class elements, the percentage was only 0.13.

In the case of Clamond's thermopile, taking data from Müller-Pfaundler's "Textbook of Physics," we get 0.037 per cent., and from N. Kayser's experiments 0.076 per cent. A Clamond thermopile heated with coke gives more favorable results. In this case we get 0.518 per cent. of the energy given out by the coke in electrical energy in the external circuit.

In Lord Rayleigh's comparison of a thermo-electric battery, consisting of German silver and iron, with a perfect heat engine, he found that the latter would yield 300 times more electric energy than the thermopile.

It seems natural to suppose that the direct transformation of heat into electrical energy should be the most advantageous manner of making this transformation, and that at some future time thermopiles will acquire great practical value. The great waste of heat arises, of course, from the fact that, owing to the smallness of the surface, only a very small quantity enters the pile at all, and some of this passes by conduction to the cold junctions, or is radiated from the external surfaces of the elements.

We now come to dynamo machines; and as a working motor of such we are thinking here of a steam engine or a gas motor, and we shall compare the relations between the useful electric energy imparted to the dynamo machine and the heat energy given out by the combustible consumed (coal or gas). We must not here alone regard the heat which passes into the water and makes it steam, but the whole heat which is given out by the combustible. We do not concern ourselves with the efficiency of the heat engine, but with that of the apparatus which converts the heat into electric energy, passing over the intermediate transformation.

In the case of a steam engine, the calculation gives 3.2 per cent. of the heat used as being converted into electrical energy in the external circuit; in the case of a gas engine, 5.85 per cent.

Hitherto we have concerned ourselves with the relation of the quantity of useful electrical energy obtained from the known quantity of heat employed in generating it by different methods, and we have shown that batteries give by far the greatest amount of electrical energy for the same quantity of heat. Thus they give ten times more than dynamo machines, and, if we speak of Clamond's thermopile with coal heating, 200 times more than thermo-electric batteries.

The relations will, however, be different if we have regard to cost. The heat used in batteries is the dearer, because here it is zinc which is burnt, while in the other cases it is coal or gas. We will therefore look at the relation between the electrical energy obtained and the cost in the three cases.

To have the same relation with all sources, we will take the proposition to determine the cost of an hourly electric energy of 500 volt-amperes as given by batteries, thermopiles, and dynamo machines.

In a Daniell battery we take into account the cost of the zinc and sulphuric acid. The copper vitriol used need not be reckoned, as its cost is covered by the deposited copper.

In the case of thermopiles and dynamos, there is the wear and tear of the apparatus, as well as the cost of the combustible used.

The following table gives the expense in the several cases. The wear and tear of the machinery is taken into account in the case of dynamos, but not in the case of thermopiles.

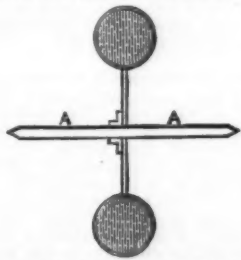
Name of Element.	Cost per hour of 500 volt-amperes.
Daniell element	1.06 Mk.
Bunsen element	1.51 "
Rebeck { Starpile	5.65 "
thermopile { Pile with straight fire-line	7.17 "
Clamond { with gas-heating	16.03
thermopile { with coal-heating	0.42
Dynamo { with steam	0.105
machines { with gas motor	0.25

These numbers show that the cheapest electric energy is given by dynamo machines which are driven by steam power.

The mark may be taken as the equivalent of 1s., or 25 cents.

A NEW DAMPING APPARATUS.

THE essential principles of the damping used to still vibrations are of two kinds: 1st, the electric induction



of currents in conductors; 2d, the friction caused by the relative motion of solids and fluids.

To the second class belong vanes moving in air or water.

The scientific investigation of the friction between fluid and solid bodies has often been carried out by means of a hollow ball, set to oscillate when filled with a fluid. The friction of the fluid on the inner wall of the hollow ball itself damps the oscillation.

Dr. Frölich has investigated the question as to what form the hollow vessel should have, so as to make this damping of the vibrations as great as possible, and has found that the best form is a hollow ring rotating round its axis (as shown in section of the figure, where the ring is supposed perpendicular to plane of paper). The ring should be well paraffined inside, filled with water, and closed by soldering.

Such rings can be placed on all instruments for measuring by oscillation, and give a damping whose strength is sufficient for practical purposes, and is unchangeable with time. The ordinary way of damping by means of a fluid, on the other hand, often requires great care in the management. — *Elektrotechnische Zeitschrift*.

THE EDELMANN VOLTAMETERS AND AMPEREMETERS.

MR. EDELMANN'S voltmeters and amperemeters are designed for use in connection with electric lighting,

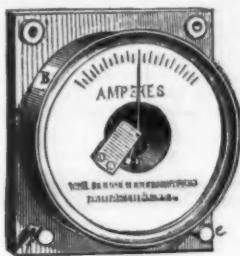


FIG. 1.

and for giving at every moment the current and potential indications necessary for showing whether the work is proceeding under normal conditions. They form part of a series of other apparatus for the same purpose. For the sake of eliminating to as great a degree as possible the variations in the constants of



FIG. 2.

the apparatus, the manufacturer uses neither permanent magnets nor springs, and he has endeavored to increase the forces set in play as much as possible, this being an indispensable condition for accuracy in reading, in practice.

Fig. 1 gives a general view of the apparatus. The

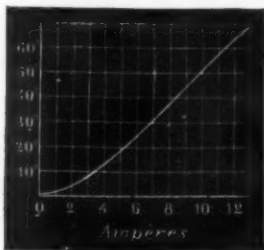


FIG. 3.

voltmeters and amperemeters differ only in their winding.

The box, B, which is provided with a glass, and is fastened to a mahogany block, contains a fixed bobbin, which is traversed by the current, and some small pieces of soft iron, the magnetization of which is varia-



FIG. 4.

ble for each value of the current, and gives rise to different positions of equilibrium.

As shown in Fig. 2, the needle, *z*, is connected with a piece of soft iron, *n*, and a counterpoise, *g*, the whole being movable around a knife edge, and the center of gravity being regulatable at will by means of the screws, *r* and *s*. The armature, *n*, as well as the fixed

piece, *m*, is placed in the magnetic field formed by the bobbin, *R*. Moreover, there is a curved piece, *p*, outside of the coil.

The equilibrium of the movable piece occurs under the action of the weight, *g*, of the repelling force exerted between *n* and *m*, and of the magnetic attraction exerted between *n* on the one hand and *r* and *R* on the other.

For feeble current values the pieces *m* and *n* are approximate, and repel each other, the force increasing with the current. In the neighborhood of 3 amperes a saturation occurs, and the principal action then is the attraction between *n* and *R* and *p*.

The piece *p* has the effect of rendering *n* less sensitive to the magnetic actions that might influence it from the exterior. Fig. 3 shows the relations between the deviations and intensity of the current, in the case of an amperemeter. As may be seen, this curve may, within the limits of practical measurements, be considered as a straight line.

The manufacturer studied the distribution of the lines of force, and of the equipotential lines, in a plane situated about one millimeter beneath the level of the pieces of iron, and for that purpose placed the voltmeter horizontally, and studied the field with a current of 50 milli-amperes, the maximum of current admissible. The direction of the lines of force was given for that of a small steel wire 4 mm. in length, and the intensity at each point by the duration of its oscillation.

Figs. 4 and 5 show the result of these experiments.



FIG. 5.

The unbroken lines are the equipotential ones, and the dotted lines those of force. In the first case the bobbin was unaccompanied by the other pieces, in the second the curved piece, *p*, was in place, and in the last two cases the pieces *m* and *n* were successively introduced. The figures marked upon the equipotential lines are simply proportional numbers. — *La Lumière Electrique*.

AN ELECTRIC LIGHT FIRE-DAMP INDICATOR.

THE Royal Commission on Accidents in Mines points out in its recently issued report a serious objection to the use of the electric light in mines, notwithstanding its many other great advantages, in that the light of an incandescent lamp being produced within a vacuum cannot admit of any device for the indication of fire-damp, such as is employed in the Davy for example. This difficulty was experienced by one of the inventors of the apparatus we are about to describe in the course of an installation of the electric light in the Lofthouse pit, Wyke, Yorks, in the summer of 1885, and a series of experiments have since been carried out with the object of devising a method of making the electric light an indicator of fire-damp.

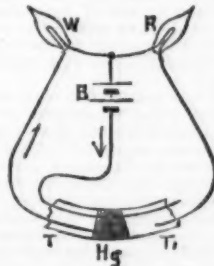


FIG. 1.

The apparatus placed before the Physical Society, at a recent meeting, is the outcome of the work of Messrs. Walter Emmott & William Ackroyd. It consists of two incandescent lamps, one with white glass and the other with red, and other necessary adjuncts, such that in an ordinary atmosphere the white incandescent lamp alone shines, but in fire-damp the white lamp goes out and the red one begins to emit its light. This is effected as follows: A porous pot of unglazed hard baked porcelain is joined by air-tight connections to a tube, a portion of which is represented by T, T¹, Fig. 1. This tube is of such an internal diameter that it will readily admit of being sealed with a small quantity of mercury, Hg. A platinum wire runs the whole length of the tube, and is connected with one of the poles of the battery, B, or other source of electricity.

Two other platinum wires in the tube run parallel with this for part of the way, as in Fig. 1, and each is connected with a lamp. The lamps, W and R, are joined, and a branch wire connects them to the other pole of the battery. In Fig. 1, the current is represented as flowing through W; when from diffusion in an atmosphere of fire-damp, the conducting plug, Hg, is driven up to T¹, the current will flow through R, and

the red light may then be taken to indicate the presence of fire-damp.

The wires being within the tube, one or other of the lamps must always be shining so long as there is a current, whether the apparatus be in an atmosphere of fire-damp, choke-damp, or air; and to prevent the mercury being driven out of the tube by too much pressure, bulbs are arranged on either side, as in Fig. 2, which presents a diagrammatic view of the apparatus.

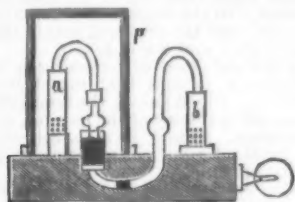


FIG. 2.—p, POROUS POT; a, b, DESICCATORS.

The inventors find an internal diameter of tubing of about 3 mm. best adapted for insuring easy mobility of the mercury. The presence of the wires within the tube has interfered with the perfection of the seal; this, however, has been overcome by the introduction of a little concentrated sulphuric acid, which also serves the purpose of preventing sparking and of lubricating the interior. The use of sulphuric acid necessitates the addition of desiccators, a and b, Fig. 2, to each end of the tube; but in cases where it has been found advisable not to use sulphuric acid, both the acid and the desiccators have been dispensed with by slightly modifying the arrangement of the wires at the lower part of the tube.

With this form of apparatus one can readily detect the presence of 5 per cent. of coal gas in a mixture of this gas with air, and with a mercury seal of less weight and closer proximity of the wires at T and T', Fig. 1,

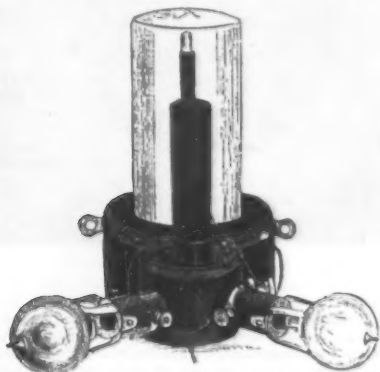


FIG. 3.

It appears possible to get any required degree of sensitivity.

Fig. 3 is a view of the apparatus about one-third full size.

ELECTRO-MAGNETIC ROTATION OF UNPOLARIZED LIGHT.

By L. SOHNCKE.

ALTHOUGH the phenomenon of the rotation of the plane of polarization by electro-magnetic forces has frequently been investigated since Faraday's discovery, their action on ordinary unpolarized light has not received any attention. Two plane polarized rays of light proceeding from the same source cause interference when they are polarized in parallel planes, but no interference is produced if they are polarized at right angles to each other. Ordinary light behaves as light polarized in parallel planes, and consequently it will lose its power of interference if by means of electro-magnetic forces the plane of undulation of one of two rays proceeding from the same source can be turned through 90°, thus furnishing us with a means of testing the question raised.

The experiment was carried out by causing the rays of unpolarized light, which would produce interference bands, to pass through a double quartz prism, whereby the interference was annulled. They then passed through two cylinders of Faraday's glass which were placed inside two solenoids, and if the current in these latter had any effect, the interference bands would again appear. The experiment was most successful, as always, on closing the circuit of a Schuckert dynamo giving a current of 20 amperes through the solenoids, the interference bands at once became apparent. It was found that not only was the plane of undulation of the light rotated by the electro-magnetic force, but that the rotation was in the same direction for ordinary light as for polarized light.—*Annalen der Physik und Chemie; Jour. Soc. Tel. Eng.*

VOLTAIC CELL WITH A SOLID ELECTROLYTE.

By Mr. SHELFORDE BIDWELL.

ITS construction is as follows: Upon a plate of copper is spread a layer of quite dry precipitated sulphide of copper; if on this a clean plate of silver is placed, and the cell joined up to a galvanometer, a slight deflection is observed, due to the unavoidable presence of moisture. If, however, the silver plate be covered with a slight film of sulphide of silver, by pouring on it a solution of sulphur in bisulphide of carbon, and evaporating the free sulphur by heat, and then placed with the prepared side down as before, a deflection is obtained far greater than, and in the opposite direction to, the former. The resistance of the cell was very great, but was enormously reduced by compression; the electromotive force was about 0.07 volt.

AN ELECTRIC FUSE.

THE ignition of mines charged with ordinary powder or dynamite—write MM. Scola and Ruggieri, in *Comptes Rendus*—presents numerous difficulties and dangers which might be entirely avoided by the use of our new electric fuses.

These fuses are composed of two copper wires, D, D, covered with cotton and coiled on a small wooden cylinder, C. Round these wires and their support is glued a paper cartridge filled with a priming composed of chlorate of potash, saltpeter, sulphure of antimony, and retort charcoal in fine powder; the last-mentioned



ingredient serves to give a slight conductivity to the mass.

The wires thus arranged are fixed at the extremity of a paper tube, A A, which contains a port-fire or a powder-match, B.

If we wish to effect the explosion of a mine charged with common powder, we reserve in the mass a narrow empty cylindrical space, by means of a pin. The fuse described is placed at the upper part of this channel. It is merely necessary to connect the two wires to an induction coil, or, preferably, to the ingenious apparatus known as a "coup de poing," to obtain at the desired moment an extra-current spark which ignites the fuse-paste. The gases produced in this combustion ignite the match, and project it with great velocity into the middle of the mine.

If we use dynamite, we add a fulminating primer, upon which the match impinges at the instant of its projection.

The use of our new fuses secures the ignition of mines, prevents any accident which might result from their hanging fire, and will, we hope, render excellent services in numerous branches of industry.

THE PROPULSION OF ELECTRIC PENDULA.

By P. H. VANDER WEYDE, M.D.

HAVING had experience with electric clocks, and largely investigated the subject, I may be allowed to make a few remarks in addition to what was published on page 261 of the *SCIENTIFIC AMERICAN* for April 24, and give some important information in regard to this matter.

It appears that Bain was the first who, forty years ago, drove a pendulum by battery power.* In his pendulum the weight was an electro magnet oscillating between two permanent steel magnets, while the motion of the pendulum, by means of varying contacts, caused a reversion of the current, and consequent change of polarity of coil and core at every swing of the same. His motive power was an earth battery, namely, a large copper and zinc plate buried in the ground. As a curiosity, I must here state that this same motive power was used in a clock exhibited by Drawbaugh at the late Electric Exhibition in Philadelphia, under the false pretense that it was a magnetic clock driven by terrestrial magnetism drawn from the earth.

We are constructed later (1848) a similar contrivance,† which differed from Bain only in the form of the magnets, while he obtained his current from a Daniell battery, as experience had shown that the gradual exhaustion of the battery influenced the amplitude of the oscillations, and caused these to become smaller and the clock to run faster. The Daniell battery is more constant than others, but as it is not absolutely so, the clocks did not keep time, until Liais, in Paris,‡ conceived in 1851 the idea to make the battery current stretch a little metallic spring, which, at the proper moment, was liberated by the contact arrangement, and pushed the pendulum with a perfectly uniform power. By this device the power driving the pendulum became independent from the strength of the battery, and the main difficulty was overcome.

In 1853, Kramer, in Germany, without knowing what Liais had done, made another device accomplishing the same purpose.§ but at the same time a new difficulty offered itself, namely, he found that, notwithstanding he used a current as weak as possible (two or three elements), the secondary current induced in the coil surrounding the iron core at the break of each contact caused sparks visible in the day time, which by their continuous repetition every one or two seconds at last affected the platinum points with which the break had been provided, so that in eight or ten days, or 400,000 interruptions, a great change in the contact points was perceptible, while finally after a few months they were destroyed and required renovation. In order to avoid such results, Fizeau had before that time succeeded to reduce largely these sparks at the break of the vibrators attached to the Ruhmkorff coil, by connecting the circuit with a large condenser of tinfoil, so as to utilize this induced current after the manner of charging a Leyden jar. This remedy could also here be applied, and was attempted by some; but as in the case of electric clocks it is not necessary to make a total interruption of the current, Kramer devised a simpler method. He introduced in the circuit a coil of German silver of a resistance some ten times greater than that of the coil surrounding the core of the electro magnet, and connected in such a way that the circuit was never entirely interrupted, but only increased and decreased for an amount of about 90 per cent.; this gave an exit for the induced currents, and the result was that with help of this device the spark at the break could only faintly be seen in the dark by help of a magnifying glass, while in the course of half a year no change was perceptible.

Some ten years later (about 1858) an electric clock company opened a store in New York city, on Broadway, near Spring Street, and exhibited there a number of electric clocks, each propelled by three or four battery cells. The method of propulsion was primitive and without

regard to the improvements made ten years before by Liais and Kramer. It was as follows: To the lower part of the pendulum was attached a horizontal bar of soft iron, at each side of which was a hollow stationary coil, in which the ends of the iron rod could freely enter when the pendulum oscillated. This oscillation caused the making and breaking of contacts, and sent the current of four cells alternately in each coil, by which device the iron bar was alternately pulled in one or the other of the coils, which kept the pendulum in motion when once started. As these clocks did not possess the devices of Liais and Kramer, to make the driving power independent of the strength of the battery, nor any precaution to guard against the final destruction of the platinum contacts, I watched them with some interest, and found that they did not keep time, as was to be expected; while in regard to the preservation of the contact points, I could make no observations, except that I saw the business break up after a short career, the glowing advertisements and testimonials notwithstanding.

In connection with this I may add that there is still another method to make the regularity of the pendulum independent from the strength of the battery power driving it, which as far as I am aware has never been applied to electric pendula. It is based on the discovery of Huyghens that the cycloid is the curve of isochronic descent, which the arc of a circle is not. A pendulum suspended in the usual way from a steel knife edge will describe circular arcs, with the knife edge as center, and oscillations of great amplitude will require more time than those of smaller amplitude, causing the clock to retard, and *vice versa*. When the pendulum is, however, suspended from a flexible connection at each side of which is a stationary curve of solid material, along which the flexible connection will bend when oscillating, and when these curves are evolved cycloids, the weight of the pendulum will describe a cycloid, the times of oscillation will be uniform, and the movement isochronous, whether the amplitude is large or small. The clock provided with such a pendulum will run at a uniform rate, whatever be the driving power of the battery. As the cycloid is the only curve of which the evolution is also a cycloid, one has only to fix two half cycloids at each side of the flexible pendulum suspension to have an isochronous pendulum.

It is curious that of late years there has been a tendency to return to the primitive method of using electricity for the purpose of moving clocks. Steinheil in Munich was the first who, in 1839, succeeded to apply electricity for the purpose of keeping a number of clocks situated at various localities in time with an ordinary central clock driven by a weight. Wheatstone, independent from this, took in 1840 a patent in England for the same purpose* while Breguet in France experimented in the same line.†

Lamont contrived in 1843 an electric method to equalize the time of various astronomical clocks by one normal time piece, while Jacobi in St. Petersburg improved upon Lamont's method.

Bain brought a great number of clocks in the same circuit, and moved them all with one central battery,‡ attached to the clock driven by a weight.

As the contact repeated every second always acted in the end injuriously upon the platinum points, Froment and Garnier in France made an arrangement to make contacts every six seconds;§ while Siemens and Halske in Germany completed their arrangement and made the contacts only once a minute,|| so that they were the originators of the electric clocks at present known under the name of "minute jumpers," which are very simple in construction, and for this reason are becoming quite common in large establishments or towns.

The system of Kerikuff differs from all the preceding in that he uses no batteries, but obtains induction currents by causing the pendulum of a central clock, driven by a weight, to move steel magnets in and out of hollow coils,* while the system of Gloesener is a variation upon the same principle.

But one of the most ingenious devices is that of Du Moncel, who causes the sun itself to equalize any number of electric clocks, situated at various distances, daily, at exactly the same time. He does this by causing a mercurial thermometer, situated in the focus of a lens, to close the circuit by the rise of the mercury** when the sun passes a certain point.

In practice, it has been found that this movement and regulation of many clocks from a central station is limited, and that not as many clocks can be driven in this way as was expected. Kramer goes into a consideration and calculation of this subject, and points out how the failure of one clock out of a hundred will also cause the other ninety-nine to fail when they are in the same circuit,†† which is the only economical arrangement.

So, taking all in consideration, if one wants an electric clock, it is the most satisfactory to drive the pendulum with a battery. The writer has since several years such a clock, and uses a single Daniell gravity cell, in which the top is covered with an inverted flask containing sulphate of copper crystals. Being closed on top, it is less subject to evaporation than any other form, and lasts from six to nine months. The driving power is a little brass ball, of half a gramme in weight. This is suspended from a short cross piece attached at one side to the upper part of the pendulum; at every alternate oscillation, this little weight is lifted up by the armature of a small electro magnet, and dropped at the next move. In this way it keeps the pendulum in motion if once started. The movement of the pendulum alternately magnetizes and demagnetizes the electro magnet by the make and break of contact between two short platinum wires, stretched at right angles one to the other. This simple arrangement has two great advantages, first of not allowing dust to prevent a full metallic contact, as there is no place for dust, and secondly, of being very easily replaced when after a few years the platinum is destroyed, while sooner or later always will be the case.

* Bulletin de l'Acad. de Bruxelles, 1840.

† Du Moncel, App. de l'El., vol. II., p. 250.

‡ Du Moncel, vol. II., p. 250.

§ Dingler's Journal, vol. 140, p. 423.

|| Shellen, El. Telegr., p. 571.

* Dubb, Anvend. Electromagn., 1873, p. 714.

** Dingler's Journal, 140, p. 425.

†† Dubb, Anv. Elect. Mag., p. 719.

* Theilend, Elec. Tel., Braunschw., 1861, p. 374.

† Dingler's Journal, vol. 108, p. 256.

‡ Du Moncel, App. Elec., vol. II., p. 261.

§ Dubb, Anw. der Elec. Mag., Berlin, 1873, p. 727.

SECONDARY ELECTROLYSIS.

By PROF. E. SEMMOLA.

ONE of the most widely known and best studied phenomena is certainly that of the decomposition of water by means of the electric current, or, as it is called, the electrolysis of water. It suffices to immerse in a slightly acidulated liquid the platinum extremities or electrodes of two conductors that start from the positive and negative poles of a battery, in order to have an immediate disengagement of oxygen at the positive anode or electrode, and hydrogen at the negative electrode or cathode.

This phenomenon may be called principal or primary electrolysis, in order to distinguish it from that which occurs between the two extremities of a single conductor entering the same liquid—a phenomenon that forms the object of this study, and that I have styled secondary electrolysis.

In my researches I have made use of a voltmeter, *a, b*, in which the platinum electrodes, *c, d*, are fixed to the vertical sides of the glass, and near the bottom.

Upon putting water slightly acidulated with sulphuric acid into the vessel, and causing a current to pass, there occurs, as every one knows, an electrolysis of the liquid, with a disengagement of oxygen at the anode, *d*, and of hydrogen at the cathode, *c*. This admitted, I interrupt the current and immerse in the water a conductor, *m, n*, of amalgamated zinc, formed of a small strip, seven centimeters in length and a few millimeters in width. This conductor, which I call the third or secondary electrode, rests upon an insulating support, *s, o*, in such a way as to be on the same level with and opposite the two principal electrodes, with which it is in close proximity. Its extremities are bent at right angles in order to better collect the gases.

If, under such circumstances, the current be again passed, we shall obtain the same disengagement of gas as before at the electrodes, *c, d*, but more hydrogen will be disengaged at the branch, *n*, of the conductor, *m, n*.

This demonstrates that the liquid is likewise decomposed by that portion of the current which traverses the third conductor. The branch, *n*, serves as a cathode, and develops hydrogen, while *m* serves as an anode, and ought by right to develop an equivalent weight of oxygen; but the latter, by the nature of the electrode, remains combined with the zinc, whence it results that there is no development of gas at *m*.

Such electrolysis, which, as I have already said, we have a right to call "secondary," is entirely independent of that which occurs at the principal electrodes; so that the quantity of hydrogen which develops at *n* is but a small fraction of that which is obtained at the cathode, *c*, and is certainly not equivalent to the quantity of oxygen that develops at the principal anode, *d*, situated opposite.

The intermediate conductor operates as a peculiar voltmeter having *m* for anode and *n* for cathode, which is the same as saying that we have two voltmeters, one within the other.

It is almost useless to remark that when things are thus arranged, we have nothing at all to do with a platinum-zinc couple, on account of the manner in which these metals are placed.

I think it well to mention that it is not necessary that the conductor, *m, n*, shall be entirely immersed in the liquid; it might very well be reversed by turning upward the convex part, which would thus be above the level of the liquid, while the two branches, *m* and *n*, would alone be immersed.

A large number of measurements have been made in order to determine the quantity of hydrogen that develops at *c*, with or without the intermediate conductor, *m, n*, by employing a pile of six or seven Bunsen couples. In certain experiments I obtained the same quantity, while in others I met with very slight variations, due perhaps to the fact that the intensity of the current varied a little.

It would take too long to report all the results in this place, and I shall confine myself to the statement that in three series, each of five observations, I obtained the following: In one experiment, 5.68 cubic meters of hydrogen, on using the intermediate conductor, and 5.65 cubic meters without it; in a second, 13 cubic meters with, and 13.2 without the conductor; and in a third, 10.57 cubic meters with, and 10.75 without the conductor. In each of these experiments the proportion of acid in the water was varied. I intend to repeat these measurements as soon as I am able to make use of a thoroughly constant generator of electricity. For the present it can merely be safely asserted that, upon employing the intermediate conductor or third electrode, the total gaseous production increases, and that we consequently obtain with the same generator of electricity a decomposition of a greater quantity of liquid.

The intensity of secondary electrolysis depends upon several factors. First, it is modified with the chemical nature of the conductor, *m, n*, and next with its dimensions and the position that it occupies. Moreover, it changes along with the proportion of acid in the water, the intensity of the current, and the varying section of the vessels, *a, b*.

As I have already said, the nature of the secondary electrode is of very great importance. If it be of platinum, and a pile of six Bunsen couples be employed, nothing at all will be obtained, and scarcely anything else will show itself than some little bubbles of gas adhering permanently to the third electrode. But if the current be stronger, and a pile of say ten Bunsen couples be used, we shall very clearly see a feeble disengagement of oxygen gas at *m*, and of hydrogen at *n*, in the usual ratio of 1 to 2.

When the third electrode is made of gold or silver, secondary electrolysis occurs, even with six Bunsen couples; but it is very feeble, and hydrogen alone is disengaged, while the oxygen remains adherent.

I should mention, moreover, that all the metals that I have employed are those that we find in commerce, and therefore naturally impure and alloyed with other metals.

Upon using easily oxidizable metals as a third electrode, the phenomenon manifests itself in full force. With such metals, as I have already observed, we obtain hydrogen, which is alone disengaged at the extremity, *n*, while the oxygen remains in combination at the other extremity, and produces oxides of a special nature. With copper, iron, brass, and zinc, the electrolysis manifests itself very freely. It is unnecessary to say that in such cases we have always taken account

of the hydrogen disengaged by the action of the acidulated water upon the oxidizable metal.

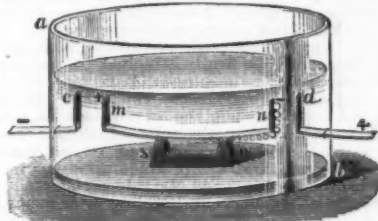
As a general thing, I have accorded preference to amalgamated zinc, because it is not attacked by the acidulated water as soon as the current is interrupted, it being merely dotted with a few bubbles of hydrogen, and that is all. If, under such circumstances, we cause a current to pass, we shall obtain an abundant disengagement of hydrogen at *n*, and it will be easily seen that the quantity disengaged here is maximum, and that it will afterward continue to decrease in measure as we approach the center, where it is null. As shown in the figure, the bubbles of gas are largest towards the extremity, *n*, and continue to decrease in measure as the center is approached, where they generally remain permanently adherent, like a very light dew.

As might have been expected, we find a neutral section in the center. In order to give an idea of the importance of secondary electrolysis, it seems to me well to recall the fact that, upon using a Bunsen pile of seven couples connected for tension, and the water in the voltmeter being acidulated 1-20, I have in one minute obtained 6.2 cubic centimeters of hydrogen at the principal negative electrode, and a little more than one cubic centimeter at the secondary electrode, *n*, with a strip of zinc, 0.6 cubic centimeter with a strip of copper, and 0.1 cubic centimeter with a strip of silver.

Upon dividing the secondary conductor (strip of zinc) into one or more parts, and arranging them in a line with one another, we find a secondary electrolysis upon each of them, with a disengagement of hydrogen toward the end that serves as a cathode. In this case the phenomenon might be styled a multiple electrolysis. Moreover, in measure as we shorten each strip, the electrolysis becomes feeble, so that it would disappear altogether were the fragment exceedingly small.

As a general thing, if we immerse in the liquid several conductors, either parallel or in a line with each other, or at a different depth, we find the electrolysis at the two extremities of each fragment.

The position of the third electrode likewise modifies the phenomenon in a great measure, the maximum effect being obtained when the said electrode is in the



line that connects the axes of the principal ones. The effect diminishes, either when we move the third electrode parallel with itself into another position in the electric field, or arrange it in such a way as to intersect the line of the axes; and such effect is minimum when the third electrode is at right angles with the line of the axes. In this latter case, the phenomenon decreases, and entirely disappears when the third electrode is made of a very fine wire.

On merely varying the proportion of acid, we likewise greatly vary the secondary electrolysis.

Nature of the liquid.	Quantity of Hydrogen in Cubic Centimeters disengaged at the Cathodes.		Ratio. <i>n</i> : <i>c</i> .
	<i>n</i>	<i>c</i>	
Non-acidulated water.	0.6	1.7	0.35
Water with 1-50 acid.	1.4	6	0.23
" " 1-30 " "	1.8	9.5	0.19
" " 1-10 " "	1	15	0.08

The annexed table shows that, in measure as the water is more acid, the primary electrolysis increases along with the secondary. But this occurs only up to a certain limit, beyond which the primary electrolysis alone increases, while the secondary considerably decreases.

Thus, in one of the numerous experiments that I performed, I obtained in one minute, by the use of water $\frac{1}{50}$ acid, a disengagement of 6 cubic centimeters of hydrogen, at the principal negative electrode, and a little less than 1.5 cubic centimeter at the secondary. With a liquid $\frac{1}{10}$ acid, I have obtained 12 cubic centimeters of hydrogen at the first electrode, and 1 cubic centimeter at the second, as when the water contained but traces of acid.

There is occasion to remark, moreover, that the ratio between the quantity of hydrogen developed at the third electrode, at *n*, and that that we have at the principal cathode, *c*, is, according to the table, maximum when the water is not acidulated, and gradually diminishes in measure as the proportion of acid is less.

Upon repeating these experiments several times, we naturally find a certain discrepancy between the results, from their not having been performed under exactly identical circumstances; but upon using more and more acidulated water, the ratio of the secondary to the primary electrolysis continues to increase.

The intensity of the current likewise much modifies the phenomenon which I am here considering. Thus, while I have, in one minute, obtained 6 cubic centimeters of hydrogen at the principal cathode, and a little more than one at the secondary zinc cathode, with 7 Bunsen couples, 4 of the latter gave 4 cubic centimeters at the first, and 0.3 at the second, so that when the primary electrolysis is very feeble, the secondary is not reproduced, even when easily oxidizable metals are employed.

The fact can be very simply explained; a portion of the current, selecting the direction of feeblest resistance, is induced by the second conductor, whose extremities thus become polarized, and operate as electrodes. In this case, the intensity of the current must increase a little bit, because the resistance of the circuit diminishes; and, in fact, if we interpose a sinegalvanometer in the circuit, we shall constantly find that the current is a little stronger when the third electrode is dipping into the liquid.

In such measurements as have been made, the intensity of the current has increased by a few hundredths up to a tenth of its original intensity, when the intermediate conductor changed in nature or dimensions.

This method might also be used for measuring the resistance of the conductor that enters the liquid. We thus ascertain why it is that, in measure as the water is more or less acidulated, and consequently the electric field is weaker, the ratio between the quantity of current induced through the third electrode and that which passes through the liquid diminishes, as well as does the ratio between the quantity of hydrogen disengaged by the secondary and primary electrolysis. Moreover, the quantity of current that passes through the secondary conductor is so feeble when but a small number of couples is employed, that it would not be capable of producing an electrolysis, or else would produce one that could not be measured.

If, on the contrary, the conductor be feebly oxidizable (and such is the case with a zinc arc), it will require but a very weak current to electrify its molecules, so that their affinity will be increased, and a decomposition of water take place.

This once more proves how intimate is the relation between the ordinary chemical action and the chemical force of the current, and how true is this principle of Becquerel's: "Strong affinities may be overcome by the simultaneous use of very feeble electric forces and properly selected affinities."—*La Lumière Electrique*.

[Continued from SUPPLEMENT, No. 351, page 8804.]

WATER-PROOF PAPER.—PARCHMENT PAPER.—TOUGHENED PAPER.—DISSOLVED PAPER.—PAPER SLABS.—PAPER LUMBER.—PAPIER MACHE.—PAPER BUTTONS.—HARDENED PULP.—PAPER LEATHER.—LEATHEROID.—WATER-PROOF PAPER BAGS.—CELLULOSE.—CELLUVERT.—VULCANIZED FIBER.—ARTIFICIAL IVORY.—ARTIFICIAL HORN.

TAYLOR'S PATENT OF 1871.

THE object of my invention is to prepare paper or paper pulp (either sized, unsized, or partially sized) in such manner as to produce a change more or less complete in the fiber or material of which the paper is composed, whereby the texture and character of the paper are altered. The paper thus treated becomes less porous, acquires increased density, strength, stiffness, and durability, resists the action of water, and may be made to assume, to a greater or less extent, the toughness, semi-transparency, and general appearance of parchment, the peculiar effect thus produced upon paper being, as regards chloride of zinc, a new fact in chemical science.

My invention consists in soaking paper, when dry, in a concentrated neutral or nearly neutral solution of chloride of zinc, either at the natural temperature of the air or moderately heated, and afterward thoroughly washing the paper in water.

The following is the general process I adopt: I take a solution of the salt called chloride or muriate of zinc, and having rendered it as neutral as may be by the addition of oxide or carbonate of zinc, I concentrate the solution, by evaporating it until it has acquired, when cold, the consistence of sirup. In this case it will have the specific gravity of 2100 or thereabout. The solution of zinc being thus prepared, I immerse or float upon its surface the paper to be treated, until it is fully saturated with the solution. The paper is then withdrawn, and the adhering liquor being removed by a scraper, roller, or any other mechanical means, it is either immediately plunged into water or allowed to remain for a short time until it is apparently dry, then plunged into water and washed therein until all soluble matter is removed. In cases where it is desirable to retain a portion of oxide of zinc in the paper, the paper, after being partially washed, is immersed in a weak solution of a carbonated alkali, and afterward thoroughly washed in water. The paper may then be pressed and dried and submitted to the ordinary processes for obtaining a smooth or glazed surface, or it may be sized or colored.

After this treatment it will be found that the paper is more or less changed—has contracted in volume, become more dense, and is less porous than before, while, at the same time, it is much stronger. When, however, it is desired that a more complete change should be produced in the paper, the solution of zinc should be moderately treated before immersing the paper; or the paper, after having been drawn through the cold solution and the adhering liquor removed, should be exposed to a gentle heat. The temperature necessary may be varied from 80° to 90° Fah. to little short of boiling water, according to the effect that is desired to be produced on the paper. It must also be borne in mind, in determining the amount of heat to be applied, that the kind of paper used, its thickness, density, the strength of the zinc solution, and the length of time during which the paper is exposed to heat, influence the result.

In general, I find that when ordinary blotting-paper is used, and the paper is heated by the application of metallic surfaces, a temperature of 120° to 140° Fah. is sufficient. A good criterion of the completion of the change is to be found in the circumstance that the paper becomes somewhat swollen and apparently dry. It also passes from a semi-transparent and rather rigid state to one that is more opaque and flaccid.

The heating of the paper may be effected in several ways: first, by bringing the solution of zinc to the required temperature; secondly, by laying the saturated paper upon smooth heated surfaces, or by passing such surfaces over it, as is done in the operation of ironing. When the paper is in the form of a continuous web, this may be conveniently effected by passing the paper between heated rollers or through a hot chamber, as is commonly done in the drying of paper. In fact, the whole operation, from the first plunging the paper into the bath of chloride of zinc, to its final washing in water, may be made a continuous process. I do not, however, claim any particular form of apparatus for doing this, as the means are so simple as to be obvious to every mechanic, and are also in ordinary use for various other purposes. I also find that this process may be applied to paper already printed or written upon with common writing-ink, whereby both the paper and writing are rendered more durable.

In some cases I dissolve, by the aid of heat, cotton

fiber, starch, dextrine, or gum in the concentrated solution of chloride of zinc, or I add to the solution of chloride of zinc the chlorides of tin, calcium, or magnesium, prior to using it; but in every case I use the substances in a state of solution, and afterward submit the paper to thorough washing with water.

If sheets of paper, after having been saturated with chloride of zinc, be pressed firmly together and a warm iron passed over them, the surfaces will become permanently united; and in this way many sheets may be joined together or vessels formed of one continuous piece.

The employment of a concentrated solution of chloride of zinc, either alone or mixed with other substances, to sized or unsized paper, and afterward washing the paper in water, substantially in manner and for the purposes hereinbefore described.

HANNA'S PATENT OF 1877.

This invention relates to improvements in the manufacture of what is known to the trade as "vulcanized fiber," and has reference particularly to a process by which the said vulcanized fiber is rendered impervious to moisture.

In the manufacture of this material it has heretofore been found impossible to produce an article which would prevent the absorption of moisture, which, unless prevented, causes the material to swell up and soften to such an extent as to soon become comparatively useless, and lose its distinctive characteristics.

This difficulty I aim to overcome; and to that end my invention consists in submitting the article or the material to a bath of nitric or sulphuric acids, or their equivalent, as hereinafter fully described and claimed.

I have discovered that, if such vulcanized fiber, or the articles made therefrom, be submitted for from twenty-four to forty-eight hours in a bath of strong nitric acid, and then washed thoroughly in water, it is rendered almost absolutely impervious to moisture in any degree, and thus the material becomes available for many purposes to which it has not hitherto been applicable. The length of time of submersion is determined by the thickness of article under treatment; the thicker it is, the longer the time required to permeate its substance.

On account of the difficulty of obtaining nitric acid of sufficient strength, I have found that it is preferable to use a mixture of nitric and sulphuric acids, the proportions depending upon their respective strength.

Though I have mentioned nitric or sulphuric acids as the preferable agents, or a mixture of the two, I do not confine the scope of my invention to their specific use, as a mixture of sulphuric acid and nitrate of potash, or a vapor-bath of the fumes arising in the manufacture of bisulphate of potash, or other equivalents, may all be found available under different circumstances, and all are but modifications of my invention.

I claim: 1. The within-described method of rendering vulcanized fiber water-proof or moisture-proof, consisting in submitting it to a bath of nitric acid, or its described equivalents, substantially as specified.

2. As a new article of manufacture, vulcanized fiber having its substance moisture-proof.

HANNA'S SECOND PATENT OF 1877.

My invention has reference to the utilization of either the liquid produced in the process of cleansing, or of the mother-liquor of chloride of zinc after it has been used in the treatment and manufacture of paper, as described in letters patent Nos. 113,454 and 114,880.

In the said letters patent, the paper or paper-pulp is described as being treated to a bath of the mother-liquor resulting from the manufacture of chloride of zinc, or the chlorides of tin, calcium, magnesium, or aluminum, or to a bath of the concentrated solution of chloride of zinc, directly produced.

For use in treating paper by this method, the solution or bath is concentrated by heat to about 65° to 75° Baumé. After being treated in the solution, the paper is removed to a cleansing-bath of clean water, in which it is washed until free from all surplus liquor. After such washing, the cleansing-bath contains a large percentage of the chloride of zinc solution; and my invention consists in utilizing the same by submitting it to the action of chemical reagents, whereby I produce other chemicals which can be sold for enough to cover the cost of the process, and thereby effect a large saving in the manufacture of such material.

In the processes above referred to, it requires about four pounds of the concentrated solution of chloride of zinc to treat one pound of paper, the cost of said solution being, at present, about six cents per pound.

In carrying out my invention, I proceed in the prescribed manner, and wash the treated paper in a cleansing-bath; but I continue to use the same water until it has absorbed enough of the chloride of zinc to raise it to from 30° to 40° Baumé, more or less. I then add to it a solution of carbonate of soda sufficient to cause a complete chemical reaction, the result being that carbonate of zinc is precipitated, and chloride of sodium remains in solution.

The superior advantage which I claim for my process over that of evaporating the solution is that the precipitated carbonate of zinc commands a high price, and can be sold for as much as, or more than, the original cost of the solution, thus giving the treatment without cost; or, being dissolved by hydrochloric acid, can be again used in the treatment of paper or other vegetable fiber, with the result as above stated.

Of course, it is obvious that the specific reagent above given may be replaced by others with similar results, differing only in degree; as, for instance, instead of carbonate of soda, carbonate of potash might be used, or any of the alkaline carbonates. In fact, we may use such reagents as will, by combined reaction, produce the desired zinc-salt, and also another salable or comparatively valuable product.

What I claim is as follows:

1. In the described processes of manufacturing vulcanized fiber, the method of utilizing the waste or cleansing-bath, holding chloride of zinc in solution, consisting in submitting it to the action of chemical reagents, substantially as set forth.

2. In the process of utilizing the said cleansing-bath, holding chloride of zinc in solution, the method of recovering the zinc by submitting the solution to the action of another solution in water, of a salt having, in its combination, an acid whose anhydrous constituent has superior affinity for the zinc, whereby the two form a new combination, substantially as specified.

PARKES' PATENT OF 1882.

Heretofore vegetable fiber and various vegetable fibrous substances have been treated with solutions, and so reduced to a pulp-like mass used to coat or to form entire a variety of articles.

In accordance with my invention, instead of using chloride of zinc or other solutions heretofore used in the treatment of vegetable fibrous substances, I employ iodide of zinc or nitrate of zinc or nitrate of lime to first obtain a complete solution of cellulose or such like substance from cotton or linen fiber, or from paper or fabric made from such fiber, or from other woody cellulose, and combine with it coloring matters or pigments, and mould or shape the mixture into various forms by pressure or otherwise; or I employ it for coating paper or other surfaces.

For dissolving the cellulose, the iodide of zinc or nitrate of zinc should be employed as neutral as possible, and concentrated to a syrupy condition of about 1°00 to 1°800 specific gravity, heated to about 200° Fah., or it may be to a higher temperature, but not so high as to cause carbonization of the cellulose or woody fiber. Although I prefer iodide of zinc or nitrate of zinc, nitrate of lime may also be used, either alone or together with the above solvents. Whether I employ nitrate of zinc or iodide of zinc or nitrate of lime as the solvent, it must be concentrated to from 1°600 to 1°800 specific gravity, and by preference heated to about 200° Fah.—say 180° to 250° Fah. The cotton or paper (whether pulped or otherwise) or fiber is immersed in the solvent, and quickly dissolves, and I continue to add fiber or paper until the solution arrives at a stiff, pasty condition, suitable kneading or mixing machinery heated to the required temperature being employed to break or blend up the compound as the dissolving of the cellulose goes on. The pasty mass may also be put by for future use, and masticated afterward.

If the cellulose solution is to be used for coating paper, textile fabrics, leather, wood, metals, and such like, it may be used thinner than when entire articles are to be shaped and moulded from it.

For coating paper, textile fabrics, and other surfaces, I prefer to use the cellulose solution in a pasty and well-blended state and heated so that it shall remain plastic. I spread it upon the paper by the use of a gauge-knife and rollers or other spreading machinery, with the solvent still remaining in it, as by so doing I find it will be firmly attached to the paper or other surface; and two or more coats may be applied if it is desired to increase the thickness. When the coating has been effected, the solvent can be removed by washing in water or alcoholic solutions. The articles so coated may be calendered or embossed, or otherwise finished, and will produce upon the paper or other substance a fine, hard, flexible surface.

Sheets and other forms and hollow ware may also be moulded from the cellulose solution while the solvent remains in it, and the solvent can afterward similarly be removed by water or alcoholic or vegetable naphtha solutions, and the articles so formed may be further finished by rolling, pressing, or otherwise to consolidate them, and give to their surface a finer and more ornamental character. For removing the solvent I much prefer to use alcoholic or vegetable naphtha solutions. The iodide or nitrate of zinc or nitrate of lime can then readily be recovered by distilling off the spirit, and, in addition, the cellulose material is left in a transparent state, whereas, if water is used for removing the solvent, the material is left in a cloudy, opaque condition.

I have also found that the solvent of the cellulose may be first removed by washing the solution in an agitating or pulping machine, and that the washed cellulose may then be pressed or rolled into sheets or other forms, whether combined with pigments or colors or not.

I have also found that I can wash and then pulp or granulate the dissolved cellulose, and color it by dyes or pigments, and in this pulped condition it does not lose the property of strongly adhering together when subjected to pressure and slightly heated in moulds or in rolling or spreading machinery. It can also be floated—as in paper-making—upon fabrics, or can be made into a substantial sheet alone. On being calendered in the usual way, it forms a fine vellum-like sheet or substance, and by these means I am able to form a new and valuable substance, as hard as ivory, tortoise-shell, or horn, and which, being free from smell, and also unflammable, may be used for an endless variety of purposes. The hard substance formed as above can be turned in a lathe, cut with a saw, and shaped or finished into figures, animals, tubes, combs, buttons, knife-handles, and other articles, plain or ornamental, and may be white or black or colored with a variety of delicate colors, pigments, or dyes, as desired.

I claim:

1. As an improvement in the process of making articles in whole or part of cellulose, the treatment with a solvent consisting of a solution of iodide of zinc or its specified equivalent, substantially as described.

2. As an improvement in the process of making articles in whole or in part of cellulose, the treatment of the dissolved cellulose with the alcoholic or described equivalent solution to remove the solvent.

3. The process hereinbefore described of making articles of cellulose and of coating articles therewith, consisting in first dissolving cellulose in a solution of iodide of zinc or its specified equivalent, then moulding the dissolved cellulose to the form of article required, or spreading it over the surface of the article to be coated, then removing the solvent by washing, and finally rolling, pressing, or calendering the article or coated article.

4. The process hereinbefore described of making articles of cellulose or partly of cellulose, consisting in first dissolving cellulose, as above set forth, in iodide of zinc or its specified equivalent, then washing out the solvent from the cellulose, and then moulding the cellulose to the form required by subjecting it to pressure in moulds or otherwise, or by rolling or spreading machinery.

TAYLOR'S PATENT OF 1884.

In many of the uses to which vulcanized fiber, gelatinized fiber, leatheroid, vegetable fiber which has been treated by the well-known sulphuric acid process, and such like material are applied, it is desirable that the material should possess more or less softness or

flexibility, and that this quality should be lasting. For instance, when the material is used for many kinds of packings, washers, etc., more or less flexibility is required, and of course it is important that the material should not become dry and hard with age, but should retain its flexibility as long as possible. I impart this permanent flexibility and softness to the fiber by subjecting it to a bath of deliquescent salt subsequent to the organic change produced in the vegetable fiber during its manufacture.

When vulcanized fiber is manufactured according to the well-known Schmidt method set forth in patent No. 113,454, the vegetable fiber or cellulose is treated either with mother-water resulting from the manufacture of chloride of zinc or other chlorides, or with a solution of chloride of zinc or other chloride. In either case, however, this active agent for producing the organic change in the cellulose to convert it into vulcanized fiber is thoroughly washed out of the fiber, and then the fiber is treated with a bath of water and glycerine or sugar-water to render it flexible.

The patent of Daniel Hanna (No. 120,380) relates to the treatment of vegetable fiber by chloride of zinc, or mother-water of chloride of zinc, and suggests that when a hard paper is required, nearly, if not all, of the solution is washed out from the paper; but when a soft paper is to be produced, comparatively little of the solution is washed out. This manner of producing flexible fiber is objectionable for various reasons, and principally because of the great difficulty and practical impossibility of producing uniform results, as it is impossible to always wash the fiber to the same degree to produce equality of flexibility in the same batch of material.

In my improved method the vegetable fiber or cellulose is first treated with the active agent, whatever it may be, to produce the required organic change, is preferably then thoroughly washed, and then subjected to a bath of a solution of deliquescent salt of a definite and known strength. The deliquescent salt may be used either alone, or a bath composed of a solution of deliquescent salt and glycerine or sugar-water may be used. While both baths give most excellent results in practice, I prefer the last named.

The method of treating vegetable fiber for the manufacture of vulcanized fiber and such like material is so well known and fully set forth in the patents referred to, as well as others, that any description here is unnecessary.

In carrying out my invention I preferably take the fiber as it comes from the cleansing-bath while yet soft and saturated with moisture, and treat it with a bath of a solution of chloride of zinc or other deliquescent salt, which bath may be of a strength of from 15° to 30° Baumé, more or less, according to the degree of flexibility it is desired to impart. When the deliquescent salt is used in combination with a glycerine or sugar-water solution, I preferably take a solution of either of the latter of from 20° to 30° Baumé, and add to it from thirty to sixty per cent, in bulk of the solution of deliquescent salt at a strength of about 30° Baumé, more or less. As before remarked, these proportions may be changed according to the amount of softness and flexibility desired.

While I prefer to take the material as it comes from the cleansing-bath and subject it to the softening baths described, I may treat the dried fiber in the same way. Of course, however, in that case the fiber would have to be immersed in the solution for a much greater length of time. The wet fiber as it comes from the bath may be immersed in the softening-solution for from six to forty-eight hours, the length of time depending upon the thickness or size of the mass immersed and the amount of softness to be imparted to it.

When working according to my improved method, as the strength of the bath is always definite and ascertained, fiber of uniform flexibility may readily be manufactured, and the material produced retains its softness for a long period of time. As above stated, I prefer to use the deliquescent salt in connection with sugar or glycerine, as I believe better and more permanent results are obtained thereby. I have used chloride of zinc as the deliquescent salt employed, though various other deliquescent chlorides may be used—as, for instance, the chlorides of tin, calcium, and other chlorides used in the manufacture of vulcanized fiber.

I am aware that in the patent of Van Bibber (No. 113,224) chloride of calcium mixed with a composition for printers' inking-rollers has been suggested as a means of rendering the rollers soft and flexible.

Approximately equal and good results—at least results much better than those heretofore attained—may be had in some cases by omitting the cleansing-bath, and taking the material directly from the bath of the active agent and immersing it in a bath of a definite strength of solution of deliquescent salt, or of deliquescent salt and glycerine or sugar-water. With a compound solution of glycerine or sugar and deliquescent salt good results may be obtained in this way.

I claim as my invention—

1. The method of treating vegetable fiber after it has undergone organic change and cleansing in the process of manufacturing vulcanized fiber and such like material, which consists in immersing it in a bath of a solution of deliquescent salt, as described.

2. The method of treating vulcanized fiber and such like material to impart softness and flexibility thereto, which consists in taking the fiber after the organic change therein has been produced in the process of manufacture, and subjecting said fiber to a bath of a solution of deliquescent salt as described.

3. The method of treating vulcanized fiber and such like material, which consists in taking the vulcanized fiber after the organic change therein has been produced in the process of manufacture, and subjecting it to a bath of a solution of deliquescent salt combined with glycerine or sugar-water, as described.

4. The herein-described bath for softening vulcanized fiber and such like material, which consists in the combination of a solution of a deliquescent salt and glycerine or sugar, as set forth.

5. The method of treating vulcanized fiber and such like material to impart softness and flexibility thereto, which consists in taking the fiber after the organic change therein has been produced in the process of manufacture, and subjecting it to a softening-bath of a solution of chloride of zinc, or of a solution of chloride of zinc combined with glycerine or sugar-water.

6. The method of treating vulcanized fiber and such

like material after it has undergone the organic change and subsequent cleansing in the process of manufacture, which consists in subjecting the material to the action of a bath of a solution of chloride of zinc, or of chloride of zinc combined with glycerine or sugar-water.

7. The herein-described bath for softening vulcanized fiber and such like material, which consists in the combination of a solution of chloride of zinc and glycerine or sugar-water.

DELMAS' HOT AIR BURNER.

THE Delmas burner has been the object of a patient study, with a view of determining the most favorable conditions for a perfect utilization of gas. It consists of an ordinary cleft steatite jet-piece inclosed in an oval globe, G, in such a way that the air cannot enter beneath. This globe is only of the height of the flame, and supports the heating apparatus. This latter consists of a flatish central chimney, H, which is surrounded by a corrugated tube, P, designed to multiply the heating surface, and ending at half an inch from the top of the chimney. This tube itself is inclosed in a jacket, D, into the lower part of which the globe is so fitted as to prevent any ingress of air.

In order to prevent loss of heat through radiation, and to still further increase the heating of the air, the entire apparatus is inclosed in a third flatish tube, C, which projects one-third of an inch beyond the globe, and which supports a reflector of tin, opal, or other material.

Under such circumstances, the air, *f*, necessary for the perfect combustion of the gas, in order to reach the burner within the globe, is obliged to rise through the annular space between the tubes C and D to the top of the apparatus, from whence it descends through the corrugated tube, P, and receives, as it does so, from the sides of the latter, all the heat due to the escape of



DELMAS' HOT AIR BURNER.

the products of combustion, *f'*, through the chimney, H. The dimensions of the air passage and of those through which the products of combustion flow secure a combustion without draught and a flame of remarkable steadiness.

This apparatus, which is manufactured by Mr. Giroud, recommends itself by its extreme simplicity. It can be substituted for an ordinary burner without necessitating any change in the fixtures, and secures a great saving by consuming but 60 cubic inches per carcel.—*Revue Industrielle*.

ON A HYPERBOLAGRAPH.

By Mr. H. H. CUNNINGHAM.

It is not an unfrequent want to be able to find a rectangle of greatest or least area contained between a curve and rectangular co-ordinate axes. In several problems connected with motion and pressure in steam engines, this is useful, and even in political economy the graphic representation of monopoly curves depends on maxima and minima of this nature. For the solution of such problems, it is often very useful to be able to describe rectangular hyperbolas, and the author has devised a machine to effect this. It depends on a mathematical property of the rectangular hyperbola which he believes to be new, and which is as follows: From a fixed point let any line be drawn to meet a fixed line, and from the point of meeting draw a line perpendicular to the fixed line and equal in length to the first line. The locus of the extremity of the second line is a rectangular hyperbola, or if from a fixed point, O, a line, O P, be drawn to meet a fixed line in a point, P, and P Q be taken perpendicular to the fixed line, so that O P and O Q be constant, then again the locus of Q is a rectangular hyperbola. In the machine the latter construction is mechanically and continuously carried out. A pencil, whose point corresponds in position to the point, Q, slides along a rule which is carried across the paper always perpendicularly to the fixed line. A fine steel wire attached to the pencil passes once round a roller at P, and is then carried to and coiled round a similar one at O. The use of a steel wire is a special feature of the apparatus, and has a great advantage over string, which, owing to the facility with which it stretches, cannot give good re-

sults. The finest wire should be used; it unrolls from the one roller as much as it laps over the other, and its use may be extended to nearly all curve-drawing machines.

CARDIAC PULMONIC BALANCE.—A CLINICAL STUDY.

By BENJAMIN WARD RICHARDSON, M.D.

THE motive powers of respiration and circulation, like other motive powers in nature, are derived from the two prime movers or forces, the attraction of the earth and the force of combustion. The air enters the lungs by the atmospheric pressure; in other words, by the attraction exerted upon the atmosphere by the earth; the blood moves and circulates through the vessels of the body by the force of combustion, the evolution of motion from matter during change of condition.

These two forces, these prime movers, always at work in the organism during its life, are each regulated by the specific mechanism of the respiring and the circulating apparatus.

The mind, receiving at first the external phenomena that are presented to it only, is wont to consider that the movements of the chest and of the heart represent the prime forces of life. This is not wonderful, for they seem as if they must be the prime forces. To the untaught in mechanism, the movement of the pendulum of the clock, or the balance wheel of the watch seems to be the prime movement of the machine. The educated, however, know that the prime force is in the weight or the mainspring, and that what seems to be the force is, after all, the mere regulating movement, the means invented by the maker to prevent the undue liberation of force. But we do not so easily divine—because we do not know so much about the animal machine—that the respiring and circulating movements are the precise natural counterparts of the regulating movements of the timepiece, and that they themselves, fed by a portion of the force they distribute or superintend, have no more means for generating force than have the parts that are under their governance.

Nevertheless, these facts are so; the movements observed in the chest and in the heart itself are but means to an end—means for the regulation of the prime animal force. Truly, by stopping the movements, we can stop the organic motions altogether; but when we stop the pendulum of a clock, we, in like manner, bring all the motion of the machine to a standstill.

By the regulating actions of the thorax and heart, nature conserves force, and gives it direction. She strikes a proportion between the amount of blood that shall come to the air surface of the lung and the amount of air that shall come to the blood surface, in given periods of time. By this arrangement the force itself is regulated at one of its sources, the amount of force liberated in the combustion of blood being determined by the combination of air with blood. The balance thus struck, during normal conditions, is refinedly accurate, the pressure of air and blood being equalized to the nicest degree. On this fineness of balance the continuity of the delicate lung structures, vesicular and capillary, altogether depends.

The natural formula of this balance may be thus expressed: In a given period of time, say one minute, the right side of the heart must so regulate the blood-pressure that there shall be the same pressure of blood on the capillary surface of the lung as there is pressure of air on the vesicular surface. In like manner, in the same time, the thoracic mechanism must so regulate the air pressure in the vesicles that there shall be the same pressure of air on the vesicular surface as there is pressure of blood on the capillary surface.

The balance thus required is regulated, not so much by the number of cardiac or thoracic movements, as by the force of the movements and their equality. But for this provision, every irregularity in the motion of the heart or of the thorax would be registered in the lung by lesion of structure. In the act of running this is well expressed. When a man commences to run, the heart invariably takes brief precedence of motion, and the sensation of breathlessness is the result. After a short time, if there be a good balance, the breathing movements come abreast of the cardiac, the breathlessness passes off, and the running is easily sustained until the force of combustion, the mainspring, fails. In short, for true disturbance of the balance on either the respirating or circulating side, there must necessarily be either direct mechanical obstruction or direct failure on one side.

DISTURBED BALANCE FROM MORBID CHANGES.

There are many accidents and many morbid conditions under which this balance, so nicely adjusted, is disturbed, with lesions of the cardiac pulmonic mechanism as the result. The lesions thus induced are of two kinds, varying simply according to the side on which the disruption of balance first takes place.

When in any case there is sudden obstruction to the column of air passing through the trachea, so that the respiring mechanism cannot bring a sufficient volume of air into the lung, the blood pressure remaining the same, there is at once congestion of lung with blood, and, according to the degree of obstruction, stasis of blood in the lung. If the tracheal obstruction be complete and instantaneous, the heart, it is true, may be suddenly paralyzed, and the congestion may be indifferently marked; but when there is time for continued action of the heart, even for a period of minutes, then there is congestion.

On the other hand, if the balance of power fail on the side of the circulation, the respirating action being continued, then there is undue injection of the lung tissue with air, rupture of vesicles, and emphysema.

Both of these positions admit of being rigorously demonstrated by direct experiment upon the inferior animals. Both are constantly demonstrated in disease of the human subject. Asphyxia by hanging, or by the exudation of plastic matter into the trachea or larynx, illustrates the first position; sudden deposition of fibrin in the right cavities of the heart, and gradual failure of the right side of the heart from degeneration of its walls, illustrate the second position.

These are common examples of break in the balance of the two mechanisms, but there are others not less important.

DISTURBED BALANCE FROM ATMOSPHERIC VARIATIONS.

Sudden exposure of the air surface of the lung to extreme cold may, and often does, break the balance on the respirating side. There is contraction of the air-passages, a rapid abstraction of caloric from blood, and a reduced oxidation of blood. On this, if the heart continue active, and the prime force of the circulation remain sufficiently long, there is, during reaction, extreme congestion, exudation, and what is called pneumonia, or congestive bronchitis.

In the opposite way, sudden exposure to heat leads to excessive action of the heart, and to a pressure of circulating blood which the respiration is unable to meet. The oxidation is intense; the venous blood becomes of arterial redness; there is no time for cooling on the respiratory surface, none on the cutaneous. The increment of temperature runs up with fatal rapidity, and the muscles are fixed, from this cause, in tetanic spasm.

I have seen a horse, ridden hard on a hot day, lose breathing power, while the circulation continued in full swing; and thereupon, with the balance broken on the pulmonic side, pass into as perfect tetanus as if it had taken strychnine, or had sustained a traumatic injury leading to tetanus.

Changes in the pressure of the air lead to broken balance on the pulmonic side when the pressure is reduced, on the cardiac side when the pressure is increased. The first of these events is witnessed in mountain climbing; the second in the coffer dam, when the workers are subjected to what has been called "caisson disease."

To some extent, and possibly to a greater extent than is generally recognized, the ordinary vibrations of atmospheric pressure produce disturbance of the cardiac pulmonic balance. In damp weather, with the pressure low, persons short of breath pant, in order to keep the breathing on a level with the circulation; while in cold, dry weather, with the pressure high, those who have feeble circulation have no sufficient power of circulation to sustain a level with the respiration.

In fact, by watching closely the influences of varying atmospheric pressures upon the cardiac pulmonic balance in the unhealthy from thoracic disease, it is not difficult to prognosticate each day from the barometer, thermometer, and hygrometer the general condition of the different classes of the afflicted.

EFFECT OF MENTAL AND PHYSICAL SHOCKS.

Sudden paralysis of the heart, as from mental emotion, severe pain, or physical shock, will break the balance on the circulating side. In cases of that most painful affection, cardiac apnea, we see this effect of disturbed balance painfully demonstrated. The patient, with the respiring mechanism in full vigor, breathes into almost bloodless lungs with nearly certain disruption of structure more or less extended. In one case of sudden death from this affection, I found the bloodless lungs as white as milk, and so infiltrated with air as to distend the chest walls, and to resist being emptied of air by the firmest pressure of the hands.

Frequently repeated physical shocks lead to a disturbance of the balance which may become permanent in character. A youth was brought to me twenty years ago who had disturbed the balance by violent muscular exercise, and in whom the heart was so powerful and irritable, that the least excitement or exertion brought on an attack of breathlessness. By absolute rest for two years, with the body recumbent, the balance was fairly restored; but to the present day any exertion or excitement, in excess, leads to an attack of dyspnea, which might easily be mistaken for pulmonic disease, having an organic seat in the pulmonary structure, if the original cause were not known.

In the asthmatic, slight causes, acting from either side and disturbing the balance, are often sufficient to provoke an acute asthmatic paroxysm. In these subjects the break leading to a paroxysm is often, perhaps most often, from the cardiac side.

EFFECTS OF VOLATILE FLUIDS.

The balance of the cardiac-pulmonic mechanism may be disturbed by the agency of various substances, vaporous and soluble, some of which we have in common use. I find that all volatile fluids which have a boiling-point as low or lower than the standard temperature of the blood, produce, when they are inhaled, obstruction in the respiratory process, and therewith extreme congestion of the lung, the pressure exerted by the blood current exhibiting a relative excess of power. On the other hand, volatile fluids, having a high boiling-point, say 140° Fah. or higher, and which produce no effect until they make the round of the circulation, tell first upon the heart, and break the balance on the circulating side. Ether and chloroform, respectively, are perfect representatives of these two classes of volatile fluids.

There are other volatile substances which, producing by their inhalation an immediate action on the nervous expanse, paralyze the heart instantaneously when inhaled in sufficient quantity, and lead to instant pallor of lung, and often to rupture of the vesicles. Nitrite of amyl is a striking substance of this class.

Substances soluble in the blood act differently, according to their primary effect, on the heart or the muscles of respiration. Tobacco paralyzes the heart first, and breaks the balance on the circulating side. Opium and aconite paralyze the respiring mechanism first, and break the balance on the respirating side.

Under alcohol the balance holds with remarkable smoothness after the first stage of intoxication is established. In the first stage the cardiac overaction takes the lead, and the respirating overaction follows. Were it not for this, every attack of alcoholic intoxication would be followed by pulmonic congestion. As it is, this danger is generally escaped, except in very hot and in very cold weather. In hot weather the escape is more difficult, because the heat aids the alcohol in quickening the action of the heart; in cold weather the escape is equally difficult, because under the influence of the cold the pulmonic function is reduced in power. Thus, from heat and cold, under alcohol, we may have similar results, congestion and congestive pneumonia, a fact which my experiments with alcohol, under varying conditions of heat and cold, singularly and systematically exhibited.

VITAL VALUE OF CORRECT BALANCE.

The balance actually broken is fatal; the balance disturbed, danger to life is imminent. The disturbance being on the circulating side, and the blood being held in partial stasis, the blood-corpuscles begin to coalesce, the lung structure begins to lose its perfect organization, and even if the cardiac power is restored, these obstacles to recovery offer serious difficulties. When the balance is disturbed on the respiring side, and the heart is left imperfectly controlled by the air pressure, then there is exudation from the blood into the pulmonary structure, reduced combustion, and increasing strain on the thoracic mechanism, with failing prime force to supply it withal. In a word, in the course of disease there is no danger so long as the balance of the respiring and circulating mechanisms is correct; that disturbed, there is danger; that actually broken, there is death.

The failure of artificial respiration, the failure of transfusion of blood in cases where the cardiac-pulmonic balance is actually broken, is due to the perfection of the break. Let the pulmonary artery be left for the briefest time empty of blood, and it cannot then be recharged. The space previously occupied with blood is filled with some gaseous product, which prevents the blood passing on from the right ventricle, whatever force be employed short of rupture of the vessel.

POINTS OF PRACTICE.

And now the last and great question comes: Can an appreciation of the disturbance of this balance, and of the seat of the derangement, be applied, in any case of disease, to the service of practice?

I. I think there are facts to indicate that when we have before us a clear case of disturbed balance from distinct and continuous obstruction to the entrance of air through the larynx, any attempt to relieve by operation—tracheotomy—must, to be successful, be made very early; and that such operation, after long struggling for breath with the lungs congested, their structure infiltrated with fluid, their blood in languid motion, and the respiring muscles exhausted by incessant labor, is all but hopeless. I do not say this to discourage the operation even under these extreme circumstances, for once I have seen it succeed when, from these conditions, hope seemed gone; but I refer to it in respect to the prognosis connected with it.

II. When in disease there is failure of balance, clearly from the cardiac side, when the heart is failing while the respiration is active, then to do anything that shall reduce the circulation is to break the balance the more completely. On the other hand, when the cardiac action is full and powerful, and the breathing slow and oppressed, the greatest benefit will often follow the removal of cardiac pressure. I still occasionally abstract blood from a vein under these circumstances, and with very decided benefit. My papers on blood-letting as a scientific practice afford more than one example where, with a failing respiration and powerful circulation, the removal of a few ounces of blood has restored equilibrium and saved life.

III. In prescribing remedies which influence, specifically, the circulation, the balance of the cardiac and pulmonic systems should always be remembered.

As experience teaches us that some volatile fluids having low boiling-points, such as ether, tend to reduce the respiring power, and that some volatile fluids having high boiling-points, such as chloroform, tend to reduce the circulating power, it were worth testing experience from experiment, in extreme cases, to see if these agents can be used, by inhalation, as regulators: ether, in cases where a relatively overpowerful respiration is working with an enfeebled circulation; chloroform, in cases where a relatively overpowerful circulation is working with an impeded respiration.

Lastly, in prescribing soluble remedies, we may, with advantage, remember their relative values as controllers of the respiring or circulating organs, and select from them according as we may be anxious to regulate the balance between air and blood. In conversing with Dr. Wilks not long since on this point, he made an observation, with which I entirely concur, on the employment of digitalis to control the rapid action of a heart made rapid in its action by the rapidity of the respiration. In lung affection where there is local pulmonary irritation, and where, under the reflex, the breathing is quickened and intensified, the heart may follow suit with a quickness of movement and height of pulse which may convey the idea of vascular overaction. But such overaction is not primary; it is the heart following the respiration at an intense expenditure of cardiac power, a possible forerunner of fatal cardiac exhaustion. In such a case any attempt to bring down the beats of the heart while the breathing remains high is to check the heart and break the balance on the cardiac side as certainly as if a weight were put on the regulator of a steam engine while the furnace was too keen and the steam-pressure too severe. Subdue the respiration by an opiate or by administration of ether, and the cardiac vehemence will subside of itself.

These and other points of practice suggest themselves when the simple but important study of the pulmonic cardiac balance is under observation. I leave it as a study, which widens greatly when it once takes hold of the observant mind.—*The Asclepiad*.

EFFECT OF CHLORIDE OF IRON ON THE TEETH.—AN EXPERIMENTAL STUDY.

By GEORGE W. WELD, M.D.

It is now, I believe, generally admitted by almost every one who, I might add, has had an opportunity of observing the effects, that the tincture of the chloride of iron, although passing transiently through the mouth and over the surfaces of the teeth, nevertheless exerts a most powerful and pernicious action on their structure.

Two things are essentially necessary before arriving at a satisfactory conclusion regarding the cause of this destructive action:

1. The composition of the tincture of the chloride of iron, *i. e.*, the nature and quantity of the acid it contains.

2. A knowledge of the quantity of the different inorganic substances contained in the enamel of the teeth.

The tincture of the chloride of iron is made from

the liquor ferri chloridum, and contains 37.8 per cent. of the dry chloride. In making the tincture of the chloride, thirty-five parts of the liquor are added to sixty-five parts of alcohol. Atfield says that the liquor which is used in making the tincture contains much free acid, which is necessary to prevent the precipitation of the basic salts of iron; it is obvious from this that the relative proportions of the iron and the acid, whatever they may be, are adjusted very delicately, and that whenever water or any other fluid is added either to the liquor or tincture the result is a constitutional disturbance, *i. e.*, the affinity existing between the acid and the iron which is held in the solution is more or less disturbed, according to the character of the fluid which is added.

Clinical observation shows that water increases the destructive energy of the tincture of the chloride of iron upon the structure of the teeth more than any other fluid, and therefore must necessarily not only cause more chemical disturbance when added to the solution, but do more injury to the teeth during the process of ingestion.

As an illustration: The effect of adding water to a simple solution of the chloride of iron, *devoid of free acid*, is to give us basic salts of iron and the separation of free hydrochloric acid.

When a tooth is immersed in a solution of the tincture of the chloride of iron, a double action takes place: 1. The chlorine unites with the calcium, forming the chloride. 2. The carbonic acid is given off, and the hydrated peroxide of iron is precipitated.

When a small quantity of the strong solution of the tincture of the chloride of iron (official strength) is placed in a test tube, and a little of the carbonate of lime added, you will observe that there is a decided and immediate action, but no precipitation occurs; in a weak solution, however, say one drachm of the tincture to the ounce of water, the iron is at once precipitated. In the strong solution there is no precipitate until all the acid is neutralized by the carbonate of lime. On adding to the solution more lime, or immediately after neutralization takes place, there is the same precipitate, *viz.*, the hydrated peroxide of iron; and this action continues until all the iron is precipitated, carbonic acid being given off continually throughout the operation, from the time the acid begins to neutralize until the last trace of the iron is precipitated. In other words, the perchloride of iron acts with the carbonate of lime precisely like an acid.

On referring to the card containing the specimens of teeth which have been immersed in solutions of the tincture of the chloride of iron of different strengths, it will be observed that those teeth which have been immersed in the strong solution for a period of twelve hours remain unaltered in their structure and appearance, while those teeth immersed for the same length of time in a weak solution, consisting of only one-half a drachm of the tincture to an ounce of water, are very materially injured. (It is impossible to show this satisfactorily in a drawing; cuts are therefore omitted.)

You will very naturally inquire why it is that a strong solution of the tincture of the chloride of iron, which, containing much more acid, and acting with a far greater energy on the carbonate of lime than the weaker solution, as you have just seen demonstrated, yet has little, if any, effect upon the lime salts of a tooth when immersed in such a solution. Before discussing this point let me call attention to an old and doubtless familiar experiment.

When a piece of zinc is placed in strong sulphuric acid (H_2SO_4), it will be observed that the acid has no effect whatever upon the structure of the zinc; but if a little water be added to the acid, we find the zinc is immediately destroyed. It is not entirely a matter of the strength of the fluids, so far as the quantity of iron or acid is concerned, but a matter of constitution or solubility.

The zinc in the strong sulphuric acid is protected from immediate destruction in the same manner that the tooth which is immersed in the pure tincture of the chloride of iron is protected, *viz.*, the surface is blocked up with basic iron salts, insoluble in alcohol, which prevents chemical action. In the case of the zinc it is the sulphate of zinc resulting from the first action, which is insoluble in the concentrated acid, that forms a protecting coat over the surface of the zinc; the addition of water dissolves this protecting sulphate, and renders further chemical action possible. In the case of a tooth immersed in the strong solution of the tincture of the chloride of iron, a similar action takes place, *viz.*, the oxide of iron first formed protects the tooth from immediate chemical action, owing to its compact adherence to its surface.

To illustrate still further, let me call attention to two other specimens of teeth on the card, which were immersed in the tincture of the chloride of iron and alcohol. Here we shall see that although the solution used contained the same quantity of the tincture, and possessed apparently the same relative strength, and immersed for the same length of time, yet no injurious effect is produced on their lime salts. The reason is due to the fact that alcohol is a dehydrating compound, and the peroxide which is formed in the alcoholic solution is of the anhydrous form, and in character very compact, adhering closely to the surface of the tooth, thereby preventing immediate chemical action, while, on the other hand, in the presence of water the peroxide which is precipitated is the hydrated form, and is flocculent in character, does not so well adhere to the surface of the tooth, or at least the product of the decomposition is more easily removed from the surface, leaving the free hydrochloric acid in the solution to unite with the lime salts with greater facility. Thus we find two forms of the peroxide of iron, *viz.*:

1. The hydrated form ($Fe_2(OH)_6$), formed in the water solution, which is flocculent and non-protecting to the teeth. 2. The anhydrous form (Fe_2O_3), formed in the alcoholic solution, which is heavy and compact, and protects the surfaces of the teeth. The following formula will show how the hydrated peroxide is formed from the anhydrous peroxide ($Fe_2O_3 + 3H_2O = Fe_2(OH)_6$).

The teeth on the card that were immersed in a solution composed of the tincture and the elixir, are affected but very little. Take for example the teeth that are immersed in an ounce of the elixir of the pyrophosphate of iron, with one drachm of the tincture of the chloride added, which was the quantity of the tincture used

in the water solutions, as shown in number three column. With water as a vehicle, the enamel of the teeth is completely destroyed in twenty-four hours; but with an elixir in combination with the pyrophosphate of iron and the tincture of the chloride, the effect on the enamel is hardly perceptible.

The elixirs are composed of nearly twenty-five per cent. alcohol, the presence of which, as we have just seen in the strong solution of the tincture and in the alcoholic, affords a protection to the enamel of the teeth in the manner described. It is to be said, however, in this connection, that when a tooth is immersed in a solution of the tincture and simple sirup, in the same proportions as above mentioned, the enamel is not much affected. This is probably due to a mechanical reason or a condition of fluidity of the solution; in other words, the presence of the sugar in solution coats the surface of the enamel, preventing chemical affinity between the acid held in the solution and the lime salts. Equally interesting are the teeth immersed in a solution of the tincture and the weak alkaline waters (notably Vichy). When a drachm of the tincture of the chloride of iron is added to an ounce of Vichy water, a slight effervescence takes place, indicating that the bicarbonate of soda in the water has neutralized a part of the free acid introduced with the iron; thus when a tooth is immersed in such a solution, the destructive energy of the iron is somewhat modified. Unless the specific nature of this preparation of iron to which I have alluded is materially affected (and by contact the peculiar odor of the tincture remains the same), I see no reason why it should not, at least in all cases of anemia, be administered in combination with Vichy. The specimens of teeth on the card show the slight effect such a solution produces on the enamel.

There is an objection to the use of alcohol, whether in the form of spirit or combined with sirup in the form of an elixir. It has recently been stated by a prominent physician that although the administration of a drug in the form of an elixir was pleasant and agreeable, and the patient perhaps cured of some particular disorder, yet it might be found after the cure had been effected that the patient had contracted a habit for strong drink. Nevertheless, alcohol in the form of a spirit is looked upon with favor by many of our best physicians, and frequently prescribed in the fevers and other affections associated with great debility.

In such cases, when, in addition to alcohol, iron is also prescribed, they could doubtless with advantage to the patient be given together, and in this manner many teeth might be preserved which otherwise would be destroyed or seriously injured. Certainly water in small quantities, so far as iron in connection with the preservation of the teeth is concerned, is literally worse than nothing; and glass tubes seem to avail but little. When a tooth is placed in a weak solution of the tincture of the chloride of iron, the first appearance of a chemical action is indicated by the appearance of numberless minute bubbles distributed over the whole surface of the tooth. At the end of five minutes, if the fluid in the glass in which the tooth has been immersed be slightly agitated, a milky white cloud will be seen floating from the surface of the enamel; and if the fluid be agitated from time to time, it will, in the course of twenty-four hours, become more or less turbid, according to the amount of the tincture of alcohol contained in the fluid.

If the tooth be allowed to stand in the solution without being disturbed, a precipitate of the phosphate of iron will in the course of thirty days completely invest the upper part of the tooth, hiding it from view. This deposit is beautifully shown in the lower right hand corner of the card. On the same column can be seen the difference in the structure of the light and flocculent precipitate found in the weak solution and the heavy and compact precipitate of the strong or alcoholic solution.

At the end of thirty days from the deposit which is formed around the tooth, there will appear a number of projections extending in an upward direction, which in appearance resemble stalagmites, and which are composed principally of the precipitate which surrounds or invests the tooth, or the phosphate of iron. In connection with this phenomenon, it may be said that it is a well known fact that in making the superphosphate of lime, *i. e.*, the soluble lime phosphate, for agricultural purposes, the manufacturer chooses the phosphates that are free from iron, for the reason that the phosphate that they have made soluble will, from contact with the iron, become in time insoluble, forming the phosphate of iron, which shows that mere contact of the iron compound, although not soluble, will cause a reaction with the phosphates.

We shall take occasion at some future time to present the results of further researches which we are at present engaged in.—*N. Y. Med. Monthly*.

FLAMINGOES.

THE birds which the ancients called *phœnicopteri* (Greek, *φοινικοπτεροι*, "red-winged"), derive their English popular name of flamingo from Spanish *flamenco*, which in turn is borrowed from the Flemish name, *flaming*, "flaming," alluding to the bright red color of their wings. Hence also the French name, *flamant* (formerly *flambant*), "flaming," "blazing."

Although these birds, through the structure of their bill, which is provided with horny scales on the edge of the mandibles, and through the form of their feet, whose front toes are connected by webs, remind us of the duck, they are connected with the Grallatores or waders by the length of their tarsi, by the slenderness of their neck, by the lank form of their body, and by the arrangement of their skeleton. It was erroneous, therefore, in Linnaeus, Wagner, and Gray to class them among the Palmipedes, alongside of the Anatides, since their true place is in the order Grallatores, where they nevertheless constitute a somewhat aberrant group. This group, it is true, is not very rich in species, but it exhibits so characteristic a physiognomy that it merits elevation to the rank of a distinct family. In fact, while the flamingoes resemble the roey ibises and the spoon-bills of Tropical America and the wood ibises of Indo-China and Eastern Africa, through the colors of their plumage, they differ completely from these waders in their very thick, abruptly bent bill, with the upper mandible much smaller than the lower, and fitting upon the latter like the cover on a snuff-box. Despite its strange form, this bill is admirably adapt-

* Synonyms: Hydrated sesquioxide of iron, ferric hydroxide.

ed to the bird's mode of life, for it is a fishing instrument that the flamingo maneuvers with much skill for picking out of the mud the shell-fish and worms that constitute its food:

Flamingoes are met with in the hot or temperate countries of the Old and New World, and are entire strangers to Southern Europe, as well as to Australia and the islands of Oceania. All have the same gait and habits, and they differ from one another only in the proportions of the different parts of the body, or in the degree of brilliancy of their plumage. Around the confines of the Mediterranean basin and in India, they are represented by a species with white plumage tinged with rose-color and set off by two blotches of carmine on the front part of the wings, the points of which latter are black. This species, scientifically known as *Phenicopterus roseus* and *P. antiquorum*, was well known to the Romans, and is several times mentioned by Pliny, Suetonius, and Martial, but curiously enough does not appear in Aristotle's History of Animals. However, these birds do not seem to be so

At the time of this first visit, May 9, Mr. Chapman found the nests entirely empty, and could not find a single egg. But a few days afterward he succeeded in getting within a distance of two hundred feet without attracting the attention of the sentinels, and, by means of his field-glass, saw the birds sitting on their nests, with their long feet bent under their bodies, their heads resting upon their breasts, and their necks gracefully curved and half hidden in their dorsal feathers, after the manner of swans at rest. It was not till May 29 that Mr. Chapman's guide succeeded in getting some eggs for him.

Mr. Henke, who stayed several years in the city of Astrakhan, saw flamingoes nesting upon the shores of the Caspian Sea in precisely the same manner as above described. The nests were conical and formed of black mud impregnated with salt. Some of them contained two or three rough-shelled eggs, and others held young birds in the down.

Finally, the inquiry made by Mr. J. W. Clark, of the dwellers along the Camargue, and the results of which

very light down of snowy whiteness, which is so sparse as to allow the skin to be seen. This latter is of a grayish shade on the body and of a deep black in the space comprised between the eye and the bill. Besides, in the young, the feet are of a blackish brown, instead of carmine, as in the adults; and the mandibles, which do not as yet exhibit the characteristic bend of the adult, are likewise of a dark shade, while in the completely developed bird they are rose-colored and have a black tip.

The chicks make for the water almost on coming from the egg, and it is very difficult to capture them. With age, their character becomes still more distrustful, and hunting them is attended with exceptional difficulties, especially in broad daylight. These birds, in fact, frequent open spaces only, and keep themselves guarded by sentinels, which, in case of danger, warn the flock by a resounding cry comparable to a trumpet call. It seems, however, that, while moulting, the flamingo, on account of the loss of its large wing feathers, is incapable of flight, and allows itself to be captured by hand. In his *Ornithologie du Gard*, Mr. Crespar relates that in the month of June, 1838, a large number of these waders were captured in this manner in Valcares Pond, and were sold in the market at a low price. According to the same author, forty flamingoes were killed in 1819 by hunters who had found them held by the feet in ice in a pond near Algués-Mortes. But, we repeat, it is rarely the case that these birds can be so easily taken; and hunters are obliged to surprise them by gliding in among the grasses, or to cause them to fall into nets stretched between two fishing boats. It is by this latter process that most of the flamingoes seen in zoological gardens are taken.

In captivity, these birds lose their natural distrust, and become quickly accustomed to their new existence. They recognize their keeper, and live in perfect harmony with other fowl, as may be seen by studying the small flock at the menagerie of the Jardin des Plantes. Without dwelling upon the other species of the family Phenicopteridae, we may recall the fact that the common species was held in high esteem by ancient connoisseurs in food. Thus, Apicius reduced to doctrinal form the art of seasoning the Phenicopteri, the celebrated Heliogabalus had dishes served on his table that were entirely composed of flamingo tongues, and Vitellius judged this dish worthy of figuring in the midst of the brains of pheasants and the tongues of murenae. Moreover, if we are to believe Brehm, the reputation of the flamingo's tongue is not undeserved, and the bird when roasted constitutes one of the most exquisite dishes that can be eaten.—Condensed from *La Nature*.

WATER AND CARBONIC ACID FROM SPACE.

SOME geologists have assumed that during the carboniferous period the atmosphere contained a larger portion of carbonic acid than at present. This speculation is based on the fact that the carbon, which constitutes the bulk of plants, is obtained by them from the carbonic acid of the atmosphere by a process of dissociation in which the leaves or other green parts of the plant employ the solar radiations to separate the carbon from the oxygen with which it is combined in the carbonic acid. This theory is not so well received now as when I attended Professor Jamieson's class in Edinburgh, but the problem which it struggled to solve still remains. It is one of great magnitude, and though commonly evaded, is so fundamental that until it is solved we must confess ourselves profoundly ignorant of the barest rudiments of geological philosophy.

To understand the magnitude of this problem, a few figures are necessary. In the first place, the quantity of carbonic acid at present existing in the earth's atmosphere, as determined by the most careful analysis, is between 0.04 and 0.05 per cent. by volume, or $\frac{1}{2500}$ part by weight over the land. Over the sea it is much less, the mean of the whole earth falling short of $\frac{1}{2500}$ part by weight. The mean pressure of the whole atmosphere is, in round numbers, 2,000 lb. per square foot, and thus we arrive at 1 lb. as the total quantity of carbonic acid over every square foot of the earth's surface. One lb. of carbonic acid (carbonic dioxide) contains but $\frac{1}{5}$ of carbon, in round numbers $\frac{1}{4}$ ounces, or the quantity contained in $5\frac{1}{2}$ ounces of ordinary coal. Therefore all the carbonic acid now existing in our atmosphere is only capable of producing a film of coal covering the earth, and weighing $5\frac{1}{2}$ ounces to the square foot. A cubic foot of ordinary coal weighs from 80 to 85 lb.; therefore the stratum of coal obtainable by using up the whole of the carbonic acid in the earth's atmosphere would be not quite $\frac{1}{16}$ of a foot, or less than $\frac{1}{8}$ of an inch in thickness.

Mr. J. L. Mott, in a communication to the British Association, 1877, concludes, as the result of careful calculations, that the average amount of unoxidized carbon deposit in the crust of the earth amounts to three millions of tons per square mile; this would be represented by four millions of tons of coal, or, in round numbers, three cwt. to the square foot. This is one thousand times more than all the carbonic acid now existing in our atmosphere is capable of producing. If the atmosphere had at any period of the world's history contained $\frac{1}{10}$ of this amount, animal life, such as indicated by animal fossils, would be certainly impossible. Therefore, some great reservoir of carbonic acid is demanded, far exceeding that ever contained in any breathable atmosphere. Besides this, for every six pounds of carbon separated from the carbonic acid sixteen pounds of oxygen must be evolved.

It is customary to pass over this difficulty rather lightly, as Lyell does when he says that "we may imagine time to have multiplied the quantity of carbon given out annually by mineral springs, volcanic craters, and other sources, until the component elements of any given number of coal seams have been evolved from below, without any variation in the mean time in the constitution of the atmosphere."

The contribution of volcanoes to the carbonic acid of the atmosphere is effected chiefly by the decomposition of limestone and magnesian rocks—carbonates of lime and magnesia. Pliny the Elder was suffocated by the carbonic acid from Vesuvius. If these are made to give off their carbonic acid by simple heating, as in a limekiln, they practically contribute no carbonic acid, as the alkali left behind is greedy for carbonic acid, and sooner or later finds it in air or water; but when the carbonates are heated sufficiently in contact with silicious rocks, the silicic acid combines with the lime



FLAMINGOES.

widely distributed on the coast of Greece as they are in Italy and Spain. In the southern part of this latter country these birds of brilliant plumage are found in winter all along the coast, wherever there are lagoons and salt marshes. They even build their nests in large numbers on a few islands at the mouth of the Guadalquivir, where they have recently been observed by the English naturalist Chapman. This gentleman, having with considerable difficulty managed to reach one of these islands, found thereon a host of nests located very near one another, and giving the ground the aspect of a vast table covered with dishes. These nests consisted of masses of mud, from two to six inches in height, containing a circular depression at the apex, and sometimes bearing the imprint of the bird's body. In the midst of them there was a sort of pond filled with brackish water, which the birds had evidently formed by digging up the earth with their bills in order to obtain the mud necessary for their nests. Finally, around this principal colony were scattered other nests—some of them isolated, and others in pairs, and rising a few inches above the surface of the water, which here, however, was not very deep.

were published in the *Ibis* in 1870, confirmed the observations of Messrs. Chapman and Henke. In fact, one of the shepherds who was interrogated by Mr. Clark remembered having, a score of years previous, found upon the tongue of land that separates Valcares Pond from the sea some heaps of sand which stood very near one another, which had an excavation in the apex, and which a hunter had told him were nests of the flamingo.

Thus we find a corroboration of the statement of Father Labat, who describes the nests of the flamingo of the Antilles (*Phenicopterus ruber*) as small heaps of clay or mud emerging from the midst of a marsh, and holding eggs which the bird deposits simply upon the beaten earth. Everything seems to prove that Catesby is mistaken when he asserts that the Phenicopteri do not sit just as other birds do, but that, when on the nest, their legs are pendent, after the manner of a person sitting on a stool.

The eggs of the rose-colored flamingo are nearly the size of those of the goose, but are much more elongated and of a chalky white. There are two or three of them to a nest. The period of incubation is from thirty to thirty-two days. The chicks are at first covered with

or magnesia, taking the place of the carbonic acid, which is released as gas.

Those who describe this as a sufficient source of supply of carbonic acid usually (or always, so far as I can learn) take no account of, and apparently do not understand, another action which is exactly the opposite, an action in which the carbonic acid of the air is absorbed and releases silicic acid. This is more potent than the volcanic opposite, though less striking, as it goes on steadily and continuously—has been going on from the earliest geological periods. It is called *kaolinization*, or the conversion of the silicates of potash and soda contained in the primary crystalline rocks into kaolin, *i. e.*, the clays that have been formed from their disintegrated and decomposed materials.

Dr. Sterry Hunt has carefully calculated the amount of carbonic acid required for the production of a stratum of 500 meters (1,640 ft.) of kaolin or clay, or clay-rock, over the whole surface of the globe, and finds that, if produced by the kaolinization of orthoclase, it must have used up a quantity of carbonic acid equal to twenty-one times the entire weight of our atmosphere, *i. e.*, $2,000 \times 31 = 62,000$ times as much carbonic acid as the air now contains. The demand for this gas in the decay of such silicates as hornblende, pyroxene, and olivine is five times as great; therefore, such a stratum produced from these would have used up 210,000 times as much carbonic acid as our atmosphere now contains.

But this is not all, nor nearly all. If the earth were ever in the heated condition usually supposed, no such carbonates as our magnesian and limestone rocks, nor other earthy carbonates from which they might be formed, could have existed; the lime, the magnesia, etc., must either have been in the caustic condition or combined with silica, most probably the latter.

The demonstrable chemical conditions necessary for the existence of such carbonates force upon us one of two alternatives. We must either abandon altogether the theory of a highly heated globe that has cooled down, or regard all the carbonic acid existing in our

and must, therefore, look for it to an extra-terrestrial source. The new hypothesis, which we here advance, starts with the assumption that our atmosphere is not primarily terrestrial, but comical, and that the air, together with the water surrounding our earth (whether in a liquid or in a vaporous state), belongs to a continuous elastic medium, which, extending through the interstellar spaces, is condensed around attracting bodies in amounts proportional to their mass and temperature. This universal atmosphere (if the expression may be permitted) would then exist in its most attenuated form in the regions farthest distant from these centers of attraction; while any change in the gaseous envelope of any globe, whether by the absorption or condensation or by the disengagement of any gas or vapor would, by the laws of diffusion and static equilibrium, be felt everywhere throughout the universe.

Those who have read my essay on "The Fuel of the Sun" (January, 1870) know that I arrived by a different path to the same conclusion as Dr. Hunt concerning the universal diffusion of atmospheric matter. I regard such diffusion into all space which is receiving radiant heat as a necessary and demonstrable operation of the firmly established laws of gaseous diffusion.

The revelations of the spectroscopic suggest a further development of this hypothesis. The characteristic feature of the spectrum of comets is the pair of bright lines a little way beyond H, in the ultra-violet region, which correspond to those obtained artificially from hydrocarbons, such as olefant gas, etc. Similar lines have been observed in the trail of meteors that have penetrated our atmosphere. The researches of Schiaparelli and others have shown an intimate connection between these meteors and comets.

In the *Gentleman's Magazine* of August, 1881, I ventured to put these facts together, and to suggest that "comets and fiery meteors, instead of being the weapons of divine vengeance, wielded for the destruction of the world, have been beneficent contributors of the chief material of its animal and vegetable life"—my supposition being that there is diffused through

weather remained cloudy the entire day, and it was not until the morrow that a maestral swept the heavens and restored their usual serenity to them.

From the estimate that has been made, it seems that the apex of the waterspout must have been between 2,000 and 2,400 feet above the level of the sea.—*La Nature*.

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The Union Electric Railway Company has extended its surface road on Ridge Ave., in Philadelphia, until it has now something over half a mile ready for operation. Its system consists in taking the electrical current from an underground conduit resembling those used on the cable road. Several very successful trial trips have recently been made, the speed being considerably greater than that of the ordinary horse car. In addition to propelling the car, the electricity is used for interior illumination, for the headlight on the dasher, and for operating the brakes.

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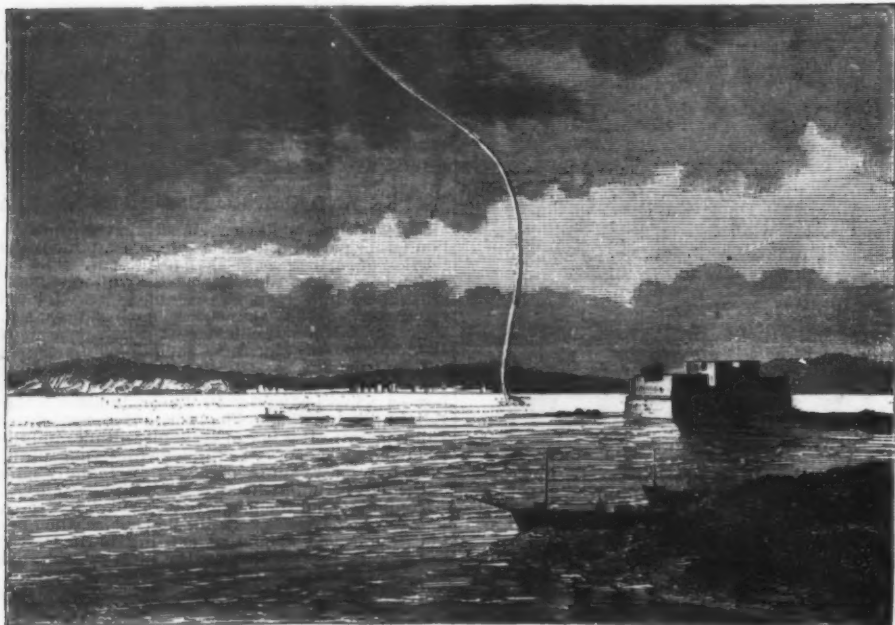
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A WATERSPOUT IN THE ROADSTEAD OF TOULON.

limestones, etc., as of atmospheric origin—as a constituent which they have obtained from the atmosphere subsequent to their cooling down.

The carbonates in the earth's crust have been estimated as equivalent "to a continuous layer of limestone 860 meters (2,821 ft.) thick, and probably to more than double this amount." (Sterry Hunt.) According to this, the earth contains in this form an amount of carbonic acid equal in weight to 100 if not to 200 atmospheres like the present, or 200,000 to 400,000 times the amount of carbonic acid now existing in the atmosphere.

Adding all these quantities together, we reach an amount of carbonic acid of atmospheric origin which utterly confounds all the prevailing notions concerning the past history of our globe in its relations to its atmosphere. Dr. Thomas Sterry Hunt, who is a philosophical chemist and geologist, one who is not satisfied with merely repeating the lessons he has learned at college and adding to them the mechanical results of laboratory and field work, has treated this subject with his customary vigor and originality in a paper communicated to the *American Journal of Science*, vol. xix., May, 1880, on "The Chemical and Geological Relations of the Atmosphere;" also in another paper in the same journal, vol. xxiii., February, 1882, on "Celestial Chemistry from the Time of Newton;" and in the preface to his volume of "Chemical and Geological Essays," published by the Naturalists' Agency of Salem. I strongly recommend the study of these papers to all who are interested in this subject. A summary of them will be found in the abstract of a memoir presented by their author to the British Association at Dublin, 1878, which is printed in their "Proceedings," and also in *Nature* for August 29, 1878.

The solution which he offers is the following, quoted from p. 356 of the *American Journal of Science*, May, 1880: "The problem still before us is, then, to find the source of the vast amount of carbonic dioxide continuously supplied to the atmosphere throughout the geologic ages, and as continuously removed therefrom, and fixed in the form of carbonaceous matters and limestones. We have shown reasons for rejecting the theory which would derive the supply either from the earth's interior or from its own primal atmosphere,

the usually assumed vacuity of space (or at least in that portion through which our solar system travels) considerable quantities of matter having the nature of volatile hydrocarbons, such as paraffin, naphthalin, benzole, etc.—most probably paraffin—which exist, according to temperature, either as solid, liquid, or gas; and which, striking our atmosphere in the form of solid particles, are heated and burnt by the collision, thereby producing both water and carbonic acid, which would thus be gradually and perpetually introduced.

At the Southampton meeting of the British Association (1882) Captain Abney read a paper, in which he stated that he had found benzine and ethyl "indicated in the spectrum at sea level, and found their absorption lines with undiminished intensity at 8,500 feet. Thus, without doubt, hydrocarbons must exist between our atmosphere and the sun, and it may be in space." (*Nature*, October 12, 1882, p. 536.)—*M. W. Williams, in Knowledge*.

A WATERSPOUT IN THE ROADSTEAD OF TOULON.

On the 4th of May, while it was slightly rainy and the heavens were darkened with thick black clouds, a waterspout made its appearance in the entrance to Toulon, at about ten o'clock in the morning, after moving from the southeast to northwest in the offing. It is rarely the case that a phenomenon of this kind can be examined so near, and so the population hastened to the shore to look at it. Driven along by a south-east wind, the waterspout moved quite slowly toward the entrance to the roadstead. Connected with a nimbus of threatening aspect by a large funnel, the elegant S-shaped column of which it was composed progressively decreased in size as it descended. Then the diameter rapidly increased till it reached the sea, which was lashed into a white foam. As soon as the base of the waterspout came into contact with the large jetty running from Grosse Tour to Saint Mandrier, it began to vanish. It broke in two at the thinnest part of the column, its lower part fell, and its upper disappeared as if attracted by the cloud.

In this latter part, several spectators observed a spiral motion directed upward and from left to right. The

